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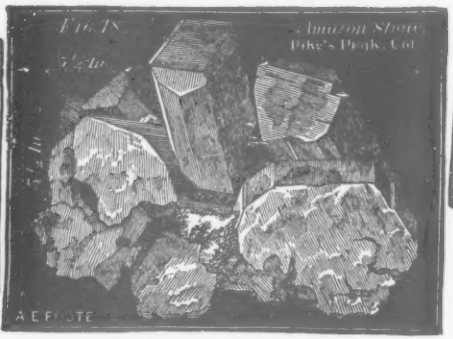

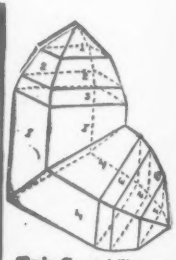

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THE

AMERICAN JOURNAL OF SCIENCE

[THIRD SERIES.]

ART. I.—*Theory of an Interglacial Submergence in England;* by G. FREDERICK WRIGHT.

UP to a very recent date English geologists were very generally agreed that the British Isles have been visited by at least two distinct glacial epochs since Tertiary times, and that during the supposed interglacial period there was a subsidence in the northern part of England, amounting to from 1,400 to 2,000 feet. The evidence most relied upon in proof of this theory is the occurrence of interglacial stratified beds of sand and gravel containing sea shells at Moel Tryfaen, near Mount Snowdon, about 1,400 feet above sea-level, and at Macclesfield, near Manchester, about 1,200 feet above the sea. At other places, also, similar interstratified beds occur at lower levels; as at Wellington, in Shropshire, about 500 feet above tide; upon the east coast, near Flamborough Head, from 300 to 400 feet; and throughout Holderness, at lower levels. North of Flamborough, also, the glacial deposits pretty continuously show a threefold division, consisting of two strata of till separated by stratified material, but the deposits here nowhere rise more than 400 or 500 feet above the sea.

But in view of accumulating facts concerning the stratification that takes place about the margin of a great glacier whose front is subject to temporary oscillations, interglacial stratified beds cease in themselves to be evidence either of absolutely distinct glacial epochs or of subsidence. The occurrence of unbroken salt-water shells in some of these deposits appears more nearly like positive proof. It would seem, however, that even this must now be regarded not only as questionable

in itself, but as connected with a theory which creates greater difficulties than it explains.

As long ago as 1874 Mr. Belt* and Mr. Goodchild† suggested that the sea shells in question may have been pushed up from the bottom of the sea, like other pebbles, by the advance of the glacial current. In 1881 Mr. Clement Reid‡ also favored the suggestion, while a little later Prof. H. Carvill Lewis took up the theory and advocated it with great vigor.§ Prof. Lewis's advocacy is the more significant, in view of the fact that, in the light of his experience in conducting with me the survey of the glacial boundary in Pennsylvania, he had just devoted two years to a survey of the glacial boundary in Ireland, Wales, and England. But his sudden death interrupted both the further field work which he was proposing and the complete digestion and publication of the extensive field notes already taken.

Investigation, however, has not flagged since Prof. Lewis's death, and the opportunities for collecting additional information in a visit which I made to England for that purpose last summer, have been largely due to the interest aroused by his work. For the facts now presented I am indebted not only to the papers enumerated below,‖ but in special degree to the

* Nature, May 14, 1874. † Geological Magazine, 1874, p. 496.

‡ Geological Magazine, 1881, p. 235.

§ Proceedings of the British Association for 1886 and 1887.

‖ Dugald Bell, Phenomena of the Glacial Epoch (Transactions of the Geological Society of Glasgow, 1889); J. H. Blake, On the Age and Relation of the so-called "Forest-Bed" of the Norfolk and Suffolk Coast (address at the Anniversary Meeting of the Norwich Geological Society, Nov. 2, 1880); H. W. Crosskey and David Robertson, The Post-Tertiary Fossiliferous Beds of Scotland: XV—Jordanhill Brickworks, and XX—Kyles of Bute (Transactions of the Geological Society of Glasgow, vols. iv and v); H. W. Crosskey, On a Section of Glacial Drift recently exposed in Icknield Street, Birmingham, and Notes on the Glacial Geology of the Midlands (Proceedings of the Birmingham Philosophical Society, vols. iii and vi); J. R. Dakyns, Glacial Deposits north of Bridlington (A Paper read before the Geological and Polytechnic Society of the West Riding of Yorkshire, 1880); C. E. DeRance, Notes on the Vale of Clwyd Caves (Proceedings of the Yorkshire Geological and Polytechnic Society, 1888); On the Post-Glacial Deposits of Western Lancashire and Cheshire (Quarterly Journal of the Geological Society for February, 1871); J. G. Goodchild, The Glacial Phenomena of the Eden Valley and the Western part of the Yorkshire–Dale District (Quarterly Journal of the Geological Society for February, 1875); Percy F. Kendall, On the Occurrence of Nassa Serrata Brocchi in the Glacial Drift of the North Shore, Ramsey, Isle of Man (Proceedings of the Manx Geological Society, 1889); On the Pliocene Beds of St. Erth (Quarterly Journal of the Geological Society for May, 1886); G. W. Lamplugh, On Glacial Shell-Beds in British Columbia (Quarterly Journal of the Geological Society for August, 1886); On the Larger Boulders of Flamborough Head and other parts of the Yorkshire Coast, Parts II–IV. (Proceedings of the Yorkshire Geological and Polytechnic Society, 1889 and 1890); Glacial Sections near Bridlington (Proceedings of the Yorkshire Geological and Polytechnic Society, 1882 and 1889; On a Recent Exposure of the Shelly Patches in the Boulder-clay at Bridlington Quay (Quarterly Journal of the Geological Society, vol. xxxvi, p. 515 and xl, pp. 312–328); On Photograph of Cliff-Section

personal attention of Dr. Crosskey and Mr. Martin, of Birmingham; of Mr. Kendall, of Stockport, and various members of the Northwestern Boulder Committee, of which he is president, and of Mr. Lamplugh of Bridlington,—all of whom have kindly accompanied me to the typical exposures of glacial deposits in the vicinities where they reside. The aid of Dr. Crosskey was specially important from the fact that he had just completed the editing of Professor Lewis's field notes, which are soon to be published. For Mr. Kendall's views I am further indebted to a systematic statement of the facts which he has prepared for me to be used as a chapter in a volume, on "Man and the Glacial Period," which is soon to be published in the International Scientific Series.

At the outset the theory of deep interglacial submergence to account for the shell-beds of Moel Tryfaen and Macclesfield encounters many most formidable objections: 1st. The subsidence must have been one which affected the north of Wales and central England, without affecting the region south of the Bristol Channel and the Thames; for confessedly there are no marks of subsidence or of glaciation over that area. 2d. There is in other places a remarkable absence of marks of subsidence over the northern part of the center of England, where it is supposed to have been the greatest. This is the more noteworthy, since in the glaciated region farther north kames abound, while at Glen Roy, a prominent feature in the landscape is the beaches formed during the existence of temporary glacial lakes, showing that the time which has elapsed since the glacial period has been too short to permit such features to be obliterated. But throughout all England there is a conspicuous absence both of such beach lines at high levels and of any other marks which would have been left by a sea margin had it continued for any appreciable time at the level of the shell-beds under consideration. 3d. This is still more remarkable from the fact that the Pennine Chain is not more than 25 or 30 miles wide from east to west, and east of

at Hilderthorpe (Proceedings of the Yorkshire Geological and Polytechnic Society, 1887); D. Mackintosh, On High-Level Marine Drifts (Quarterly Journal of the Geological Society, 1881, pp. 351–369); Fred W. Martin, On Some Sections of the Drift between Soho and Perry Barr, near Birmingham (Proceedings of the Birmingham Philosophical Society, vol. iv, part II, pp. 364–370); First Report upon the Distribution of Boulders in South Shropshire and South Staffordshire (Proceedings of the Birmingham Philosophical Society, vol. vi, part I); Aubrey Strahan, On the Glaciation of South Lancashire, Cheshire, and the Welsh Borders (Quarterly Journal of the Geological Society, 1886); C. Reid, Geology of Holderness and of Cromer (Geol. Survey); Woodward's Geology of England and Wales is a storehouse of accurate information upon this as upon all other subjects of which it treats; R. M. Deeley, The Pleistocene Succession in the Trent Basin (Quarterly Journal of the Geological Society for November, 1886); G. W. Lamplugh, On the Drifts of Flamborough Head (Quarterly Journal of the Geological Society for August, 1891).

Macclesfield there is an entire absence upon its flanks both of glacial deposits and of beach lines. 4th. The shell-beds are strictly confined not only to the area which was demonstrably covered by glacial ice, but to those more limited areas which were reached by ice that is known to have moved in its way over shallow sea bottoms. 5th. The assemblage of shells is not such as could have occurred in one place in the ordinary course of nature. There are associated together in these deposits cold-water forms with warm-water forms, rock-haunting species with sand- or mud-loving species, and in no case has a shell been found in these beds with its valves in apposition.

An interesting illustration of this latter point is brought out in Mr. Kendall's paper "On the Occurrence of *Nassa serrata* Brocchi, in the Glacial Drift of the Northern Shore, Ramsey, Isle of Man." This mollusk is now characteristic of the Mediterranean Sea, and cannot endure even the present temperate climate of the Irish Channel, yet specimens of it are found in the glacial deposits on the Isle of Man. It is in the highest degree improbable that this mollusk could have lived where it was found under any conditions that have been supposed to exist since the close of the Tertiary period. The theory that it was transported from the remains of Pliocene beds on the shallow bottom of the Irish Sea is certainly the most natural if only one can grant that it is conceivable. Other shells found in the glacial deposits in Northwestern England and Wales almost as much out of place are *Cytherea chione* L., *Mitra* sp., and *Turritella triplicata* Brocchi. It is worthy of note, also, that Prof. Edward Forbes early called attention to the fragmentary condition of the shells in the beds of the northwest of England, and to their general distribution through the till. Speaking of the Moel Tryfaen shells he says: "I have lately examined them carefully with a view to see whether they indicate an ancient coast-line or beach, or an ancient sea-bottom. But they cannot be regarded as indicating either, being a confused mixture of fragments of species from all depths, both littoral and such as invariably live at a depth of many fathoms. . . Such deep- and shallow-water species mingled could at no time have lived together, or been thrown upon one shore."*

During a visit this summer to Ketley, near Wellington in Shropshire, in company with Dr. Crosskey, Mr. Martin, and Prentiss Baldwin, we were fortunate enough to discover an unusually large collection of nearly perfect shells in the interstratified glacial deposits of that place. We could not indeed determine that there was till underneath the sand (which was here twenty-five or thirty feet at least in thickness), but there

* Memoirs, Geological Survey, vol. i, p. 384; quoted by Dugald Bell.

were several feet of till overlying the sand, and a thin stratum of gravel at the junction of the two. In this gravel Mr. Baldwin discovered several slightly worn shells and on further examination forty or fifty well-preserved specimens were brought out. All these were identified by Dr. Crosskey as belonging to species now common on the English coast. The elevation above the sea would vary only a little from 500 feet. A few miles from the same locality, at an elevation above the sea of about 700 feet, Dr. Crosskey had previously discovered in the glacial deposits other shells which were of a decidedly arctic type. It is extremely improbable that both could have lived in that locality amid the conditions involved in the interglacial hypothesis, as the temperature which would be favorable to one would be destructive to the other. But on the supposition that both had lived and died in succession upon the bottom of the Irish Sea, and then had been transported by the moving ice to near their present position, where the till was subjected to temporary water action sufficient to sort out a portion of its material, everything is intelligible and consistent.

Various reports have also come from Scotland of arctic shells in glacial deposits at some distance above sea-level. Those found near Airdrie have been most written about, and were the highest reported, being 510 feet above the sea. But closer examination shows that they also may be explained in accordance with the theory of Professor Lewis. This Sir Archibald Geikie practically admits in the second edition of his "Textbook of Geology," saying that "the layer containing them may have been transported by an ice-sheet" (pp. 897, 902). Mr. Dugald Bell informs me that after carefully examining all the alleged instances of elevated shell-beds in the glacial deposits of Scotland, there is no clear proof of any glacial submergence of more than 200 or 300 feet, and the evidence for even that amount is questionable.

As to the conceivability of the transportation of shells in the till, many significant facts have recently been brought to light. The till in the vicinity of the shell-beds mentioned, and in other places where the ice has moved inland from the sea-bottom, contains a great number of shell fragments indiscriminately mixed with the mass. I have even seen in a mass of boulder clay the half of a bivalve, with its cavity filled with sand, which had kept its place under the shell as it was shoved along; thus serving to protect it from being crushed. As long ago as 1884, Mr. Lamplugh, in examining the dry dock which was then being excavated in Esquimault Harbor, Vancouver, discovered evidence that most of the glacial shells which were found in the drift there had "been pushed up into

the gulley by ice in its passage southward across the harbor," for they were so scattered through the unstratified mass that it was impossible to draw a line between the shelly and the shell-less clay.* In the glacial deposits surmounting the chalk cliffs near Flamborough Head, Mr. Lamplugh showed me elongated masses of sandy material containing well-preserved shells, but which were included in till, and had evidently been drawn out by the shearing movement to which the whole mass was subjected. There could be little question that in this instance the mass had in some way been pushed up from the sea bottom by the same ice-movement which had carried thither the rest of the till. Here the elevation was between 200 and 300 feet, and I see no reason why the causes operating to produce that amount of movement and elevation might not under favorable conditions have transported similar masses to the elevation of the shell-beds at Moel-Tryfaen.

In recent speculations upon the movement of ice too exclusive attention has been given to its analogies with the motion of a semi fluid, forgetting that under a mechanical thrust ice moves like a solid, and may plough up and push along before it whatever is in its way. Indeed, as I recall the phenomena at Muir glacier, I feel confident that this is what is taking place on the bottom of the inlet. A large number of the icebergs are formed by the falling off of the precipitous ice-front, owing doubtless to the fact that in the ordinary motion of the glacier the upper strata move faster than the lower. At times I saw such masses break off in columns more than 250 feet in height, and extending below the surface of the water, but the fractures did not reach to the bottom of the ice, for occasionally an immense mass in front of the ice-wall would rise bodily out of the depths of the water, bringing up much dirt with it. This projecting foot of the ice may perhaps have been moved forward bodily at the bottom of the inlet by successive mechanical thrusts of the moving mass of ice behind. So in analogous situations where there is a concentration of lines of pressure from behind, we can conceive that material would be gradually thrust up in front of the ice without much attrition. At any rate, the fact that the material is so raised and pushed along in front of the ice I think will have to be accepted.

Returning now to the specific glacial phenomena in England, it would seem that they can be generalized under one glacial epoch, upon the following scheme, which is based upon the facts as they are now reported. The beginning of the glacial period was marked, in the seas surrounding England,

* Quarterly Journal of the Geological Society, Aug. 1886, p. 283.

by the southerly retreat of the Pliocene fauna and the incoming of subarctic and arctic species; so that shells of diverse nature became commingled all over the bottom of the Irish and North Seas. Scandinavian glaciers advanced over the shallow North Sea till they reached the shores of England at Flamborough Head, where they were met by the glaciers that had been slowly coming down from southeastern Scotland and northeastern England. This latter movement of the ice was compelled to hug the shore by the Scandinavian glacier, and its boulders are found only as far south as Flamborough Head. The Scandinavian movement reached pretty generally to the line extending from Flamborough Head to London.

Contemporaneous with this movement over the North Sea, glaciers began to push out in all directions from the northern part of Wales, having their center in the broad elevated area of the Arenig mountains about twenty five miles southeast of Snowdon. Towards the east this movement extended across Shropshire and the southern part of Staffordshire to a line extending from Litchfield, through Birmingham, and Bromsgrove to the Severn Valley. But meanwhile a more powerful ice-movement was under way, originating in the snowfields of Eastern Ireland, Southwestern Scotland, and the Lake District in England. The glaciers from these centers, meeting in the Irish Sea, advanced to the north shore of Wales, and in divided currents passed over Anglesey on the west, and on the east through the broad Vale of Chester which separates the Welsh Mountains from the Pennine Chain by a distance of 60 or 70 miles. Immense quantities of Scotch and Lake boulders were thus transported into the valley of the Severn as far as Wolverhampton, about half way between Wellington and Birmingham. This northern ice seems to have predominated over, and pushed aside, the weaker movement from the Welsh Mountains, which had deposited the band of boulders just mentioned, extending from Litchfield to Bromsgrove. I shall be surprised if future explorations do not reveal Welsh boulders underneath the Scotch drift, so extensively developed near Wolverhampton. It is in this northern drift that the shell-bed discovered by Mr. Baldwin at Wellington occurs.

The triple stratification spoken of as characterizing the marginal deposits near Flamborough Head, and in Lancashire and Shropshire, need not necessitate anything more than a local recession of the front, followed by a subsequent corresponding advance. Indeed, it is evident that the problems of the glacial margin in England closely resemble those in the United States, and Professor Lewis's observations require the same corrections for the personal equation in England that we have had to make for him in America,—corrections which he

himself had begun to make at the time of his lamented death. When, in 1880, Professor Lewis conducted the glacial survey of Pennsylvania with me, we were laboring under the mistaken idea that the margin of the glaciated area was everywhere marked by a pronounced terminal moraine, and we did not pay sufficient attention to the so-called "fringe" of glacial deposits which nearly everywhere extends a greater or less distance in front of the moraine. In my own subsequent work west of Pennsylvania I devoted my main efforts to the determination of the boundary of this fringe, leaving the interior moraines to be filled at leisure. The correction of our determinations which has been made by Mr. Max Foshay in Western Pennsylvania, and that by Messrs. Salisbury and McGee of Professor Cook's work in New Jersey, had already been foreshadowed both by Professor Lewis and by myself,* but, as we rightly supposed, nowhere in Pennsylvania and New Jersey does the fringe extend many miles south of our moraine.

In England Professor Lewis's moraine as reported to the British Association needs about the same correction to determine the extreme limits of the ice as is required in Pennsylvania. Almost everywhere in England there was a fringe of glacial debris in front of Lewis's moraine, but in England no more than in America does it seem to be necessary to interpret this fringe as the remnants of an earlier and distinct glacial period. The close conformity of the boundary of the fringe to that of the more pronounced glacial deposit seems to point clearly to the operation of a common cause; for it would seem in the highest degree improbable that two distinct glacial periods should so closely correspond in the marginal line of their deposits. Certainly we should not make this supposition except in the presence of facts which will not allow of a simpler explanation.

Oberlin, O., Oct. 16, 1891.

* See The Ice Age in North America, pp. 135, 136.

ART. II.—*The Permian of Texas;* by RALPH S. TARR.

FROM the time of the publications of Marcou and Shumard on the Geology of the Southwest to the present, the existence of Permian in Texas has been reported by various observers. Many have doubted its existence, but Prof. C. A. White* has brought forward conclusive evidence on this point and it is not now doubted that a large part of Texas is occupied by Permian beds. Much remains to be done in this region before the distribution of these strata through space and time is thoroughly understood. In the first and second annual reports of the Texas Geological Survey, Mr. W. F. Cummins has added many facts of interest to our knowledge of the Permian of Texas, which he estimates to have a thickness of fully five thousand feet.

A detailed study of the Carboniferous beds beneath the Permian, both in the eastern and western side of the basin, and a reconnoissance trip across the Permian deposits are the basis for the following remarks upon the Permian, the excuse for their publication being the limited information on hand in regard to this formation.

The Permian of Texas occupies a broad, gentle syncline in the Carboniferous, the western arm being a part of the Rocky Mountain uplift. Its present boundaries, and consequently its former extension, have not been ascertained. Many hundred square miles are covered by these strata in the sub-humid and arid belt of central Texas, the Pecos River forming, approximately the western boundary, while on the east the strata do not extend much farther than Abilene.

In lithologic character the strata are distinctive and, except near the contact, not to be confounded with the Carboniferous. They are chiefly beds of clay, sandstone and conglomerate, strikingly red in color. Limestone beds also occur, these usually being a pale gray, quite characteristic, though often stained on the surface by the red clay from the red beds. In addition to these strata there are beds of gypsum and of salt, and in the center of the district all the water is rendered unpalatable by the presence of these salts. Most of the beds are unfossiliferous, but Dr. White has described thirty-two species of invertebrate fossils from the Texas Permian, and Prof. Cope fifty-seven species of vertebrates. It is upon this basis that the beds have been referred to the Permian.

It is the object of this paper to indicate the sequence of events which have led to deposition of the Permian beds in

* Am. Nat., xxiii, p. 109, Feb., 1889.

this district. The Carboniferous rocks of central Texas have been divided by the writer* into five divisions, based upon lithological and faunal characteristics, as follows: Richland Sandstone, Milburn Shales, Brownwood Limestone, Waldrip Coal Measures, Coleman Limestone and Clays. The history here indicated is one of gradual submergence until the time of the Brownwood limestone, then an emergence continued through the time of the Coleman strata, which are infra-littoral beds. The Brownwood beds contain the typical marine fossils of the Carboniferous, the Waldrip coal measures combine with these the land flora, and these conditions continue into the Coleman beds.

The latter are the highest of the Carboniferous strata and near the Permian have less character than lower down. The series consists of alternating beds of limestone and clays and the presence of clay is everywhere evident, even in the purest limestones. Shore lines, proved by ripple-marks, reptile tracks, coal seams and other signs, show that at this time the Carboniferous beds were in part subjected to denudation. It is probable that the denudation of these rocks was in large measure the source of supply of the clays of the Coleman beds, and the unconsolidated nature of the coastal strip accounts for the general absence of conglomerates and sandstones.

The shallowness of the water and its muddy character gave rise to or permitted the extension of a new fauna into the seas. That the clear water animals which aided in the formation of the Brownwood limestone still existed in the neighborhood is well proved by their frequent recurrence in certain purer beds of limestone in the Coleman series. They were temporarily forced out by changed conditions and again and again allowed to return. This repeated alternation, both lithologic and faunal, is characteristic of the Coleman beds, but the predominant lithologic character is a muddy water deposit and the fauna a mud-loving one, including such species as Myalina, Pinna, Allorisma, Bellerophon, and the like.

On the western border of the Permian area the same general series of rocks is found in the Carboniferous of the Guadalupe mountains. The lower rocks are here shallow water deposits, followed by deeper water limestones of great thickness, and these in turn by an upper series of alternating beds. Shore lines are absent here, however, proving that this point was not the exact western coast line. Shumard has called these beds Permian, but I have shown in a manuscript report in the hands of the State Geologist of Texas for publication, that they are really Carboniferous, this being proved by palæontologic, lithologic, and stratigraphic evidence.

* First Ann. Rep. State Geol. Survey of Texas, 1890, pp. 201–216.

The Permian occupies the basin between these two Carboniferous areas, which are several hundred miles apart, the basin being a syncline formed by the west dipping Carboniferous of the east and the east dipping rocks of the Guadalupe and other mountains of western Texas. The Permian strata are themselves folded into a very gentle, almost imperceptible, syncline, being almost, if not quite, conformable to the gently dipping Carboniferous beds on which they lie.

The line separating the Carboniferous from the Permian on the east is very indistinct, being traceable only with difficulty. Mr. Cummins reports an overlap or slight unconformity at this contact, though its exact value is not determined as yet. Where seen by the writer there seemed to be an almost imperceptible gradation from upper Coleman to Permian. Small overlaps abound in the Coleman series and it is possible that the overlap reported by Mr. Cummins has but slightly more value, though this is suggested only tentatively.

The facts stated above show in later Carboniferous times a shallow water condition at points several hundred miles apart. In the east, in particular, the conditions are those of a shallow sea skirt by newly made land of unconsolidated strata. It cannot be affirmed from the evidence at hand that this was a Mediterranean sea, but indications point to that conclusion. The great extent of similar beds, in both central and west Texas, are rather against the supposition of estuarine conditions. I conceive for this period a condition not unlike that of the present Gulf of Mexico. The Paleozoic and pre-Paleozoic core of central Texas was skirt with the recently added coastal strip of Carboniferous strata, and the connection with the Arkansas and Indian Territory mountains was complete. What formed the enclosing barrier on the south and west we have no means of knowing in the present meagre knowledge of the geology of these regions.

This is not pure unconfirmed conception, for the subsequent events of Permian time point quite conclusively to this explanation. That the Permian in its most typical development was a completely enclosed sea is proved beyond a doubt by the nature of its beds. In no other way can the numerous layers of gypsum and salt be accounted for. The redness of the clay and sandstone beds is then easily explained, though for this other explanations are possible. The peculiar sickly gray color of the limestone is that of an inland sea deposit, the remarkable absence of fossils in most of the beds points to the conclusion already drawn, and the abundance of vertebrate fossils of land and inland sea types is thus readily accounted for. The presence of extensive conglomerates with very large pebbles

derived from points as far distant as the Indian Territory, seem hardly capable of origin except in an inland sea with a tolerably arid climate, or else by glaciation.

The Permian was undoubtedly deposited in an inland sea in which salt and gypsum were also deposited. The small break, if any exists, between the Permian and Carboniferous, shows that in point of time these two formations were immediately associated, the one succeeding the other. This gradation is also proved by the fossils. One of the distinctive Permian types, Pleurophorus, occurs in the Coleman beds, while the same species of Bellerophon, Myalina and others, are common to the two series of beds. The Permian conditions are, therefore, foreshadowed in the Carboniferous, and probably, also, the conditions which culminated in Permian times in the completely enclosed dead sea were in Coleman times indicated by the gathering in of shore lines and the partial enclosure of a Mediterranean sea. The change of fauna from Carboniferous to Permian, and also the close resemblance of the two in many respects, as well as their wide divergence in others, may be thus explained. An enclosed sea would destroy some species and admit of the introduction of others to meet the changed conditions. A temporary destruction of some part of the barrier might admit marine types which in the lapse of time may have changed to new types.

In summary it may be said that the object of this paper is to show that the Permian of Texas is, like other areas of Permian, such as those in Europe, a deposit in large measure made in an inland sea, at certain times in its history a dead sea. This condition was foreshadowed in later Carboniferous times not only in the lithologic nature of the strata and in the fauna, but also in the topographic conditions, the later Carboniferous being in all probability deposited in a Mediterranean sea more or less completely landlocked. The Permian was the immediate successor of the Carboniferous, being separated, if at all, by a very slight break, the marked difference in the nature of the beds and the character of the fauna being due rather to changed conditions than to actual time break.

ART. III.—*The Chemical Composition of Iolite;* by O. C. FARRINGTON.

As is well known the formula of iolite has never been satisfactorily established. This is chiefly for the reason that the state of oxidation of the iron, in the analyses hitherto published, has not been determined. Stromeyer,* Gmelin† and Schütz,‡ who made the earlier analyses, regarded the iron as protoxide. Scheerer,§ however, in 1846, in connection with analyses of iolite from Kragerö, urged that it was more probably present as sesquioxide, his reason being stated as follows:

"Das Verhältniss des Sauerstoffs der Kieselerde zu dem der Thonerde und zu dem der 1 und 1 atomigen Basen ergiebt sich hiernach wie: $\ddot{S}i$ 26·20 : $\ddot{A}l$ 15·26 : $\dot{R}$ 5·48 wenn man nämlich annimmt, dass die geringe Menge Eisen als Oxydul in Mineral vorhanden sei. Diess dürfte aber schwerlich der Fall sein, da der analysirte Cordierit fast völlig farblos war und auch nicht den geringsten Stich ins Grünliche zeigte, während es bekannt ist, dass verhältissmässig sehr kleine Quantitäten Eisenoxydul hinreichend sind, um einen (nicht pulverformigen) Silicate eine deutlich grüne Farbe zu ertheilen, sobald diess natürlich nicht durch andere färbende Substanzen verhindert wird. Nimmt man daher gewiss mit mehr Recht das Eisen in Zustande des Oxyds an, so wird das Sauerstoffverhältniss $\ddot{S}i$ 26·20 : $\ddot{R}$ 15·64 : $\dot{R}$ 5·26."

This conclusion of Scheerer has been accepted by most later writers. Rammelsberg,‖ regarding the iron as sesquioxide, deduces the generally accepted formula, $2MgO, 2R_2O_3, 5SiO_2$, although the ratios are not very satisfactory. He also suggests $Mg_3R_6Si_8O_{28}$ as a possible formula. Water seems to have been disregarded.

At the locality in Guilford, Conn., recently described by Dr. E. O. Hovey,¶ iolite occurs as stated by him, as a constituent of the rock mass. This locality was visited by the writer, and it was also found that veins of more coarsely crystalline material, running through the gneiss, contained the mineral in grains as large as a walnut and even in pieces of sufficient size for hand specimens. These large grains are very clear and transparent, and show none of the tendency to alteration so characteristic of the iolite from other localities.

The exceptional purity of this material led the writer to make a chemical analysis of it, and care was taken to use only those grains which were perfectly clear and showed the charac-

* Unters., Rg. Min. Ch. † Schwgg J., xiv, 316. ‡ Pogg. Ann., liv, p. 565.
§ Pogg. Ann., lxviii, p. 319. ‖ Mineralchemie, 1875, p. 652.
¶ This Journal, III, xxxvi, 57.

teristic pleochroism of the mineral. A determination of the state of oxidation of the iron was included in the analysis, FeO being determined by decomposition of a separate portion with hydrofluoric and sulphuric acids and titration with potassium permanganate. Water was determined directly, by fusing about a gram of the mineral with dry sodium carbonate in a Gooch tubulated crucible and collecting in a chloride of calcium tube. The precaution was taken to surround the first crucible with another containing sodium carbonate, so that no products of combustion from the flame could penetrate the red hot platinum and render the result too high. The analysis gave the following results:

	I.	II.	Mean.		Ratio.	
SiO_2	49·44	49·56	49·50	·825	·825	5.
Al_2O_3	32·97	33·04	33·01	·324	·326	1·98
Fe_2O_3	·35	·41	·38	·002		
FeO	5·11	5·13	5·12	·071		
MnO	·32	·27	·29	·004	·335	2·03
MgO	10·39	10·46	10·42	·260		
H_2O	1·65	1·58	1·62	·090	·090	0·54
	100·23	100·45	100·34			
Sp. Gr.	2·607					

From this it will be seen that nearly all of the iron is present as protoxide. The analysis also shows the ratio of $SiO_2 : R_2O_3 : RO : H_2O$, to be very nearly $5 : 2 : 2 : 0{\cdot}5$.

In order to test these results by comparing different material an analysis was also made of iolite from the well known locality at Haddam, Conn., the specimens being very kindly furnished by Prof. Geo. J. Brush from his private collection.

This analysis resulted as follows:

	I.	II.	Mean.		Ratio.	
SiO_2	49·25	49·03	49·14	·819	·819	5·
Al_2O_3	32·81	32·87	32·84	·322	·326	1·99
Fe_2O_3	·58	·67	·63	·004		
FeO	5·06	5·01	5·04	·070		
MnO	·19	·19	·19	·003	·333	2·03
MgO	10·51	10·30	10·40	·260		
H_2O	1·81	1·88	1·84	·102	·102	0·62
	100·21	99·95	100·08			
Sp. Gr.	2·610					

Here the percentages of Fe_2O_3 and H_2O are slightly larger than in the other analysis, but this might almost be expected

on account of the strong tendency of the Haddam mineral to alteration. The ratios, however, as will be seen, are almost exactly the same as those given by the Guilford mineral. The formula of iolite is therefore $H_2O \cdot 4(MgFe)O$, $4Al_2O_3$, $10SiO_2$, the ratio of MgO : FeO being in these two analyses very nearly 7 : 2. The theoretical percentages according to this formula are given below, and for comparison, the mean of each of the two analyses calculated to 100 per cent, the small quantities of Fe_2O_3 and MnO being reckoned as Al_2O_3 and MgO respectively.

		Calc. to 100.	
	Theory.	Guilford.	Haddam.
$10SiO_2$	49·40	49·41	49·21
$4Al_2O_3$	33·60	33·17	33·30
$\frac{2}{5}(4FeO)$	5·27	5·40	5·24
$\frac{7}{5}(4MgO)$	10·25	10·40	10·41
H_2O	1·48	1·62	1·84
	100·	100·	100·

These results show satisfactory agreement, and the percentages, it may be said, do not differ materially from those of the hitherto published analyses except in the state of oxidation of the iron. The fact that the iron is present as FeO, in spite of the lack of green color, which caused Scheerer's conclusion to the contrary, shows how little reliance is to be placed on color. Indeed, in a recent description of colorless iolite from Brazil,* Dr. Groth expresses the belief that the usual violet color of the mineral must be merely due to a pigment and not to any essential constituent. For the purpose of determining the nature of the water, about a gram of the Guilford mineral was subjected to increasing temperatures until constant weights were obtained at each. The results were as follows:

	100° C.	300° C.	Faint redness.	Full redness.	Total.
Loss in weight.	none	0·63	0·87	0·10	1·60

Up to full redness the mineral remained light in color but on further heating, over the blast lamp, it turned black, baked together and showed a slight increase in weight, owing doubtless to oxidation of the iron.

It will be seen that the percentage lost by heating to full redness is the same as that of water found by actual determination. Hence loss by ignition at this degree of temperature can safely be taken as representing the amount of water. In the Haddam iolite it was therefore determined in this way. It is possible that too intense heating may account for the

* Zeitschr. Kryst., vol. vii, p. 594.

small percentage of water (0·50 per cent) found by Jackson in one of his analyses. All other analyses thus far published show amounts of water between 1 and 2·5 per cent, the average from six analyses being 1·74 per cent.

The high temperature required to drive off the water shows that it is practically all constitutional. If present as hydroxyl, it is possible that it combines with Mg to form the univalent radical (MgOH). The recent investigations by Clarke and Schneider* seem to indicate that, if the above molecule is present in a silicate, it can be decomposed by the action of dry HCl gas, so that an equivalent of $MgCl_2$ can be dissolved out by water. An experiment, conducted to test this point, gave no satisfactory results. About a gram of the mineral was heated in a current of the dry gas for 8 hours and nearly constant weight was attained. On leaching, however, with water and a drop of nitric acid, only 0·14 per cent of MgO went into solution, so that no definite conclusion could be drawn from this result.

On digesting a sample with strong aqueous HCl for three days, on the water bath, the following results were obtained:

		Ratio to per cent in complete analysis.
Undecomposed mineral	23·20	
SiO_2	36·79	·75
Al_2O_3 with Fe_2O_3	30·50	·78
MgO with MnO	8·04	·77
HO_2	1·84	
	100·37	

From the above it is seen that about 76 per cent of the mineral had dissolved and since the different constituents were about equally affected, it seemed probable that by longer treatment the mineral could be completely decomposed. Accordingly another sample was digested, on the water bath, for fifteen days. The result showed the supposition to be correct, since the insoluble residue was found to be 49·95 per cent or very nearly the percentage of SiO_2 in the mineral. The mineral therefore is completely decomposed by long treatment with hydrochloric acid.

In conclusion the author wishes to express his especial indebtedness to Prof. S. L. Penfield, for much valuable assistance and advice rendered during the work.

Mineralogical Laboratory, Sheffield Scientific School,
New Haven, May, 1891.

* This Journal, III, xl, 303, Dec., 1890.

505.A5J1

ART. IV.—*On a Series of Caesium Trihalides;* by H. L. WELLS. *Including their Crystallography;* by S. L. PENFIELD.

IN the course of some experiments with caesium compounds, bromine was added to a concentrated solution of caesium chloride with an astonishing result. There was instantly formed a bright yellow precipitate, so dense as to nearly solidify the liquid. The substance readily dissolved on warming the liquid, and, on cooling it, large crystals of a yellowish-red color were formed which were found to be $CsClBr_2$.

In view of the fact that KI_3 was already known,* this discovery made it probable that a series of caesium trihalides could be obtained. An attempt was accordingly made to prepare each of the following possible members of such a series containing chlorine, bromine and iodine.

1. CsI_3	6. $CsCl_2I$
2. $CsBrI_2$	7. $CsBr_2$
3. $CsBr_2I$	8. $CsClBr_2$
4. $[CsClI_2]$	9. $CsCl_2Br$
5. $CsClBrI$	10. $[CsCl_3]$

As a result, all the members of the series except the two enclosed in brackets were isolated.

These eight trihalides are easily made, being much less soluble than the normal halides. They crystallize beautifully, have remarkably brilliant colors and some of them possess an unexpected degree of stability.

Method of preparation.

Each of these compounds can be made by dissolving, with the aid of heat, the appropriate normal caesium halide and the halogen or halogens indicated by the formula in the proper amount of water, or, in the single case of $CsBrI_2$, in weak alcohol, and cooling to crystallization. The caesium salt used in making the mixed trihalides is preferably the one which is not decomposed by the halogen or halogens added. In most cases the presence of an excess of the normal halide is desirable in order that the halogens, especially iodine, may readily dissolve and not separate out again on cooling, but the same result may also be obtained by the use of weak alcohol. Details of preparation will be given for each body separately.

* Jörgensen, J. pr. Ch., II, ii, 357; Johnson, J. Chem. Soc., 1877, 249.

Color.

In the following list the compounds are arranged in order, from the darkest to the lightest. The colors given, unless otherwise specified, are for crystals of considerable size, for when the bodies are obtained as precipitates or when the crystals are pulverized they are lighter in color.

CsI_3 Brilliant black, nearly opaque; powder brown.
$CsBrI_2$ Dark reddish-brown; thin crystals transmit deep red light; powder dark red.
$CsBr_2I$ Deep cherry-red.
$CsClBrI$, $CsBr_2$, $CsClBr_2$ Yellowish-red each having a somewhat yellower tint than the one preceding it.
$CsCl_2I$ Orthorhombic variety, deep orange. Rhombohedral variety, pale orange.
$CsCl_2Br$ Bright yellow.

Stability on exposure.

The five bodies containing iodine are much more stable than the others, and will bear long exposure to the air at ordinary temperatures with very slight superficial change. This exposure in some cases may be continued for a week or more in warm weather without producing any marked alteration of color, but they constantly give off a slight odor and finally begin to whiten. The three compounds containing no iodine usually become white in a few hours on exposure, but even these can be preserved indefinitely in tightly corked tubes. Experiments showed that $CsBrI_2$ whitened more rapidly than $CsBr_2I$, also that $CsClBr_2$ decomposed more rapidly than $CsCl_2Br$. This indicates that their stability does not entirely depend upon the volatility of the halogens contained in them, a point which has a bearing on the constitution of this group of bodies, and which will be considered subsequently.

Behavior when heated.

The following table shows the temperatures of complete decomposition as determined by the change of color to white. They are only approximate since they represent gradual changes which vary somewhat with the rapidity of heating. The melting-points are also given. In open tubes these are usually sharp, but in sealed tubes often very gradual.

	Melts in open tube. (uncorr.)	Melts in sealed tube. (uncorr.)	Becomes white in open tube. (approximate.)
CsI_3	210°	201°–208°	330°
$CsBr_2I$	246°	243°–248°	320°
$CsClBrI$	238°	225°–235°	290°
$CsCl_2I$	238°	225°–230°	290°
$CsBrI_2$	208°	155°–190°	260°
$CsBr_3$	whitens	180°	160°
$CsCl_2Br$	whitens	205°	150°
$CsClBr_2$	whitens	191°	150°

Behavior with solvents.

All these bodies except $CsBrI_2$, which is almost completely decomposed by water, can be recrystallized by treating with warm water and cooling the solution. There is usually some decomposition during this operation, accompanied by the separation of iodine or the volatilization of this or the other halogens.

All the trihalides containing iodine can be dissolved in alcohol and recrystallized from it. There is usually a slight deposition of normal halide at the same time, which can be avoided by adding a little water to the alcohol. CsI_3 is much more soluble in alcohol than in water. The other iodine compounds, with the exception of $CsBrI_2$, which decomposes with water, are apparently more soluble in water. Those bodies containing no iodine are all decomposed by alcohol, leaving a white residue. Mixtures of alcohol and water are good solvents for all the trihalides.

Ether has no immediate action on the more stable compounds, CsI_3, $CsBr_2I$, $CsClBrI$ and $CsCl_2I$, but it decomposes all the others with separation of normal halides. When $CsBrI_2$ is thus decomposed, pure CsBr is left.

Crystallography.

The crystallization of the caesium trihalides is orthorhombic. The salts form an isomorphous group, the chief features of which will first be given, followed by a brief description of the different individuals.

The forms which have been observed are:

a, 100, i-$\bar{i}$	*g*, 012, $\frac{1}{2}$-$\bar{i}$
b, 010, i-$\bar{i}$	*d*, 011, 1-$\bar{i}$
c, 001, *O*	*f*, 021, 2-$\bar{i}$
m, 110, *I*	*e*, 102, $\frac{1}{2}$-$\bar{i}$

Of these *m*, *d* and *e* are the most prominent and usually determine the habit of the crystals. Either *m* or *d* usually predominates to such an extent that the crystals are prismatic in the direction of the vertical or the brachy-axes. The dome

f is very common but is usually too small to give a characteristic habit, and is therefore omitted from most of the figures. The face *g* was observed only on CsI_3. The pinacoids are variable in their development, but commonly one and frequently all three can be found on a single crystal. Pyramidal faces are practically wanting. In the examination of a great many crystals but one was found (of $CsBr_2I$) on which a single pyramidal face occurred; this replaced the edge between *m* and *d* and had the symbol 132, $\frac{3}{2}-\breve{3}$. The cleavage is perfect parallel to *c*.

An idea of the similarity of the different salts may be obtained from the following table, in which the axial ratios* and three of the prominent angles are given. The angles which were chosen as fundamental are marked by an asterisk, the others are calculated, and in all cases the measurements showed close agreement.

		I	II
		a : *b* : *c*	*a* : *b* : *c*
Series with iodine	CsI_3	0·6824 : 1 : 1·1051	1 : 1·4655 : 1·6196
	$CsBrI_2$	0·6916 : 1 : 1·1419	1 : 1·4460 : 1·6511
	$CsBr_2I$	0·7203 : 1 : 1·1667	1 : 1·3882 : 1·6196
	CsClBrI	0·7230 : 1 : 1·1760	1 : 1·3831 : 1·6268
	$CsCl_2I$	0·7373 : 1 : 1·1920	1 : 1·3563 : 1·6167
Series without iodine	$CsBr_3$	0·6873 : 1 : 1·0581	1 : 1·4550 : 1·5395
	$CsClBr_2$	0·699 : 1: -----	1 : 1·430 : -----
	$CsCl_2Br$	0·7186 : 1 : 1·1237	1 : 1·3917 : 1·5638

	$m \wedge m$, $110 \wedge 1\bar{1}0$	$d \wedge d$, $011 \wedge 0\bar{1}1$.	$c \wedge c$, $102 \wedge \bar{1}02$.
CsI_3	*68° 37′	*95° 43′	78° 0′
$CsBrI_2$	*69 20	97 34	*79 5
$CsBr_2I$	*71 32	*98 48	78 0
CsClBrI	*71 44	*99 15	78 15
$CsCl_2I$	72 48	*100 1	*77 54
$CsBr_3$	*69 0	*93 14	75 10
$CsClBr_2$	*69 56		
$CsCl_2Br$	*71 24	*96 40	76 0

CsI_3 and $CsBr_3$ are almost identical in axial ratios, but it is surprising that the chemically intermediate compounds, $CsBrI_2$ and $CsBr_2I$, are not crystallographically intermediate.

A very remarkable relation exists between the first five compounds in the table, all of which contain iodine and are arranged in the order of their molecular weights. The ratio of two axes remains nearly constant throughout, while the third varies.† Exactly the same relation exists between the

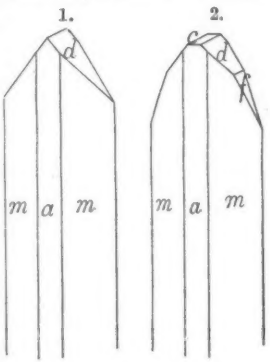
* The ratios are given in two ways: I, with $\breve{b}$ as unity, as is customary; and II, with $\breve{a}$ as unity, in order to show more clearly the relation between $\breve{a}$ and $\dot{c}$.

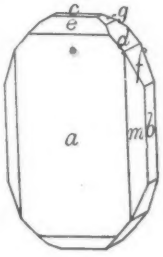
† Several series of organic compounds with analogous axial relations have been observed by Groth (Berichte, iii, 449) and by Hintze (Berichte, vi, 593.)

three compounds containing no iodine, but in this series the ratio between the two constant axes varies slightly from the corresponding ratio in the iodine compounds.

If an arrangement according to molecular weights is made with all the compounds containing bromine, or in like manner with all those containing chlorine, a symmetrical series of axial ratios is not formed. This leads to the conclusion that the two series given in the table have a special significance, and that iodine, with the highest atomic weight, plays an important part in the constitution of the first, while bromine acts in the same way in the second. Since several of the compounds contain only a single halogen atom of highest atomic weight, it follows that a single atom throughout exerts an influence on the symmetry of the series. This peculiar part played by an iodine or bromine atom may be explained by supposing it to be closely united either with the caesium or with one of the other halogen atoms. It seems probable from these considerations that the three halogen atoms in these compounds do not have similar positions in the molecule, and consequently that the trihalides are not compounds of trivalent caesium but have some other structure.

CsI_3.—Of this salt, crystals from both aqueous and alcoholic solutions were examined. On the former the forms *a*, *c*, *m*, *d* and *f* were observed. The habit was different from anything else in the series, being needle-like, with *a* and *m* in the prismatic zone, terminated by *d*, fig. 1, or by *c*, *d*, and *f*, fig. 2. The crystals did not give very satisfactory reflections, but the best measurements, from a number of selected crystals, agreed closely with those given in the table. The crystals examined were 20–30^{mm} in length and seldom over 2^{mm} in diameter. On the crystals from alcohol, the forms *a*, *b*, *c*, *m*, *g*, *d*, *f* and *e* were observed. The habit is shown in fig. 3. There was a tendency in the crystals to arrange themselves in parallel position forming plates, showing large *a* faces, but the separate individuals were small, scarcely over 3^{mm} in greatest diameter. The faces gave excellent reflections. The crystals are black, transmit a brownish red light only on the thinnest edges, and are too opaque for optical examination.

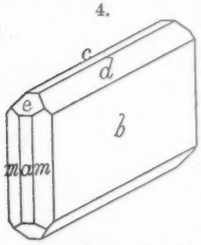




$CsBrI_2$.—On two separate samples of this salt the forms *a*, *b*, *c*, *m*, *d*, *f* and *e* were ob-

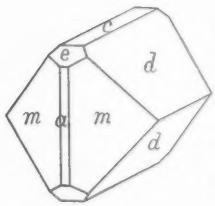
served. The crystals are thin tables somewhat lengthened in the direction of the brachy-axis, fig. 4. On examining the general table, it will be seen that this is the only one of the first five salts, in which the angle $e \wedge e$ varies considerably from 78°. Here, the variation amounts to a little over one degree, but, in all probability, this is not to be accounted for by imperfections in the crystals or inaccuracy in the observation, for from two different crops of crystals good reflections and almost identical measurements were obtained. The crystals were only a fraction of a millimeter in thickness and not over 10^{mm} long in the direction of the brachy-axis. With the polarizing microscope the tables show a decided pleochroism. For rays vibrating parallel to the $\dot{c}$ axis the color is dark brown, almost opaque, while for vibrations parallel to $\breve{a}$ it is a rich reddish brown. A similar, though less marked, pleochroism was observed in the remaining salts of the series, but owing to the inability to obtain orientated pinacoid sections, it could not be studied satisfactorily. In convergent polarized light, the phenomena were not very distinct, but with the tables of $CsBrI_2$ apparently an obtuse bisectrix could be seen, the optical axis being in the macro-pinacoid $\breve{a}$.

4.



$CsBr_2I$.—On this salt the forms *a*, *c*, *m*, *d*, *f* and *e* were observed. The habit is shown in fig 5. The crystals were brilliant and gave excellent reflections. Those submitted for measurement were about 3^{mm} in greatest diameter.

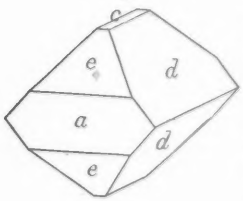
5.



$CsClBrI$.—On this salt the forms *b*, *c*, *m*, *d*, *f* and *e* were observed. The habit is like fig. 5, but much longer, or prismatic, in the direction of the brachy-axis. The crystals were about 2^{mm} in diameter and 10 in length.

$CsCl_2I$.—This compound is dimorphous.

6.

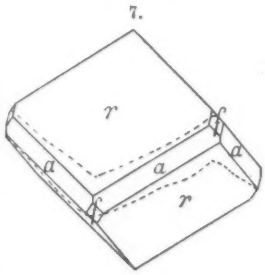


On the orthorhombic modification the forms *a*, *c*, *m*, *d*, *f* and *e* were observed, but *m* and *f* are usually wanting. The habit is shown in fig. 6. The crystals were about 2^{mm} in diameter.

The hexagonal, rhombohedral, variety occurred in curious saddle-shaped scales, with bright crystal faces only along the edges. The forms which were observed are *r* $(1, 10\bar{1}1)$, *f* $(-2, 02\bar{2}1)$ and *a*

(i-2, $11\bar{2}0$), fig. 7. Only that portion is perfect which is included between the irregular dotted lines, the upper and lower angles of the rhombohedrons being truncated by irregular warped surfaces. In their growth the individuals of a whole series of crystals, with similar orientation, are piled upon one another in the direction of the vertical axis. The scales are about 6^{mm} in diameter.

7.



The measurement which was taken as fundamental is:

$r \wedge r$, over a, $10\bar{1}1 \wedge 01\bar{1}\bar{1} = 99° 48'$

giving for the length of the vertical axis, $c = 0\ 96363$. The following measurements were also made:

$a \wedge a$	$60° 0'$, $60° 1'$, $59° 59'$	Calculated $60° 0'$
$a \wedge f$, $\bar{1}2\bar{1}0 \wedge 02\bar{2}1$	$37° 45'$	" $37° 49'$

The remaining compounds containing no iodine, were much more unstable than those previously described. By making the measurements in a cold room very satisfactory results were obtained, the crystals retaining enough luster to give good reflections, even after they had suffered considerable decomposition.

$CsBr_3$.—The forms observed on this salt are b, m and d. The habit is short prismatic, with either m or d predominating, while b is usually wanting. Single crystals are sometimes 10^{mm} in length, but groups of small crystals are more apt to occur.

$CsClBr_2$.—The only forms observed on this salt are m and c. The habit is short and stout prismatic. Single crystals are sometimes 15^{mm} in length.

$CsCl_2Br$.—The forms observed on this salt are c, m and d. It crystallized in stout prisms, over 10^{mm} long, terminated like fig. 1.

Method of analysis.

The samples were prepared for analysis by pressing on paper. The drying was not always very good, both on account of the haste sometimes necessary to avoid too much decomposition, and on account of the great tendency of the crystals to contain cavities filled with liquid.

Caesium was invariably determined by weighing the normal halide produced by heating. In some cases where the resulting normal halide was slightly contaminated by a higher halogen, this was replaced by the proper one before weighing.

Where two halogens were present they were determined in the usual way by weighing their silver salts and determining the loss in weight of these when heated in chlorine. In the cases where all three halogens were present, use was made of the extremely satisfactory method described by Gooch and Ensign.*

CsI_3.

This can be made by dissolving about one-fourth the theoretical amount of iodine in a solution of one part of caesium iodide in ten parts of water. It generally gives a crop of brilliant, slender crystals. If a larger proportion of iodine is used, the substance generally separates in the form of crystalline plates without distinct faces. They are possibly a dimorphous form of the substance. If weak alcohol is used as a solvent instead of water, the theoretical amount of iodine can be taken and a well-crystallized product is obtained.

The following numbers show the composition:

	Found		Calculated for
	Slender Crystals.	Plates.	CsI_3.
Caesium	25·41	23·71	25·88
Iodine	72·67	....	74·12

When iodine is being dissolved in a warm aqueous solution of CsI, or when an attempt is made to dissolve CsI_3 in warm water, a heavy black liquid is formed at about 73° which solidifies on cooling to a crystalline mass. It is much richer in iodine than CsI_3 and probably contains a higher polyiodide. Analyses of the substance gave varying results, and although most of these approached the composition CsI_{11}, it is still uncertain what body this is. The low melting point of the substance is remarkable since CsI_3 melts at 210° and iodine at 114°.

To find the solubility of CsI_3 in an aqueous solution of CsI, the mother-liquor from a crop of crystals deposited at about 20° was analyzed. It gave:

CsI 16·99 per cent.
I (free) 0·416 per cent or CsI_3 0·842 per cent.

The specific gravity of this mother-liquor was 1·154, hence 1 c.c. contained 0·0097gCsI_3. The body is so insoluble that, were we to use CsI in the place of KI in making a volumetric iodine solution, we could only obtain, at ordinary temperatures, a solution which would be about $\frac{1}{24}$ normal.

*This Journal, III, xl, 145, 1890.

$CsBrI_2$.

Iodine dissolves in considerable quantity in a hot aqueous solution of caesium bromide, but it nearly all separates on cooling. It is therefore necessary to use a mixture of alcohol and water in preparing this trihalide. A good crop of crystals was obtained by dissolving one-half the theoretical iodine in a solution of one part of caesium bromide dissolved in two parts of water and one part (by volume) of alcohol.

The following numbers show the composition of the crystals.

	Found.	Calculated for $CsBrI_2$.
Caesium	28·54	28·48
Bromine	18·11	17·13
Iodine	52·01	54·39

$CsBr_2I$.

This may be made by dissolving the theoretical amounts of iodine and bromine in a solution of one part of caesium bromide in ten parts of water. A considerable excess of bromine does not interfere with its formation.

The crystals have the following composition:

	Found.	Calculated for $CsBr_2I$.
Caesium	31·32	31·67
Bromine	37·63	38·09
Iodine	29·57	30·24

The solubility of this substance in water was approximately determined by estimating the free halogens volumetrically in the mother-liquor from a recrystallization at about 20°. The amount found corresponded to 4·45 per cent of $CsBr_2I$.

[*$CsClI_2$.*]

Repeated attempts to make this substance, by using concentrated solutions of caesium chloride and iodine in mixtures of water and alcohol and cooling to low temperatures, invariably failed.

CsClBrI.

This may be made by dissolving about one-fourth of the theoretical bromine and iodine in a solution of one part of caesium chloride in five parts of water. If an excess of caesium chloride is not taken the product will contain too little chlorine and too much bromine.

An analysis of the product, properly prepared, gave:

	Found.	Calculated for CsClBrI.
Caesium	34·24	35·42
Chlorine	9·36	9·45
Bromine	19·96	21·30
Iodine	32·36	33·83

If a large excess of bromine is used, an impure product results as is shown by the following analysis of a sample thus made:

	Found.
Caesium	36·11
Chlorine	9·36
Bromine	27·70
Iodine	24·83

On attempting to recrystallize the CsClBrI a product of a darker red color is formed, sometimes accompanied by the separation of some iodine. The following analyses were made of products of recrystallization:

"A" was from a single recrystallization. "B" was recrystallized three times, a little alcohol being added the last time to keep iodine in solution. "C" was recrystallized five times, each time with the addition of a large excess of bromine.

	A.	B.	C.	Calculated for CsClBrI.	Calculated for $CsBr_2I$.
Caesium	32·69	33·22	----	35·42	31·67
Chlorine	3·32	5·02	2·70	9·45	0·
Bromine	31·56	28·30	32·50	21·30	38·09
Iodine	30·91	31·78	30·99	33·83	30·24

These analyses show that the recrystallized body approaches $CsBr_2I$, but that a part of the chlorine is very tenaciously held. The excess of bromine used in the case "C" had apparently no effect, probably because caesium and iodine were present in equivalent quantities, whereas, in the case previously given, in which an excess of bromine was used in presence of much caesium chloride in preparing the body, there was evidently a contamination with $CsClBr_2$.

$CsCl_2I$.

This body is dimorphous, the form apparently depending upon the presence or absence of a large excess of caesium chloride in the solution from which it crystallizes.

The rhombohedral variety is usually obtained by adding iodine in the proportion of one atom to one molecule of caesium chloride dissolved in about ten parts of water, then passing chlorine into the liquid heated nearly to boiling until the iodine just dissolves, and finally cooling. If an excess of

chlorine is used, the body $CsCl_4I$ is formed corresponding to KCl_4I discovered by Filhol.* This new caesium compound will be described in a future article in connection with several other new bodies of the same class.

The orthorhombic variety of $CsCl_2I$ can be obtained by using three or four times as much caesium chloride as in the other case, the other conditions remaining unchanged.

The following analyses of two separate products of each of the two varieties were made.

	Rhombohedral. Found.		Orthorhombic. Found.		Calculated for $CsCl_2I$.
Caesium	39·20	39·92	38·43	40·00	40·18
Chlorine	20·72	21·08	19·78	20·75	21·45
Iodine	37·81	38·21	38·97	38·88	38·37

On recrystallizing either form of this substance, from solution in hot water, the rhombohedral variety is usually formed, owing to the lack of an excess of caesium chloride. It is not unusual, however, to obtain at first, as the solution cools, slender needles evidently of the orthorhombic variety, which afterward become surrounded by rhombohedral crystals.

$CsBr_3$.

To make this substance, one half the calculated amount of bromine is added to a solution of one part of caesium bromide in three parts of water, the whole is heated with vigorous shaking until the liquid bromine disappears and then slowly cooled. Crystals gave on analysis:

	Found.	Calculated for $CsBr_3$
Caesium	35·12	35·66
Bromine	61·53	64·24

In preparing this body, there usually remains, when the liquid bromine disappears on heating the solution, a heavy reddish liquid much lighter in color than bromine. It is without doubt a higher polybromide and it probably corresponds to the easily fusible substance already mentioned as a probable higher polyiodide. An investigation of its composition will soon be made.

$CsClBr_2$.

The formation of this body was mentioned at the beginning of this article in connection with the discovery of the new series of salts. It can be made by adding about one half the theoretical bromine to a solution of caesium chloride in about five parts of water, dissolving by heat and cooling.

* Michälis, "Anorgan Chem.," 3, 102; Gmelin-Kraut, II, 1, 82.

The analyses of two products are given below. The "precipitate" resulted from adding bromine to a cold caesium chloride solution, and, being finely divided as well as the most unstable compound of the series, it suffered a considerable amount of decomposition although time was not taken to dry it thoroughly.

	Found.		Calculated for $CsClBr_2$.
	Precipitate.	Crystals.	
Caesium	40·62	42·14	40·49
Chlorine	12·64	13·24	10·81
Bromine	39·61	42·93	48·70
Water	6·45	1·72	0·
	99·32	100·03	100·00

$CsCl_2Br$.

This substance may be made by adding the calculated amount of bromine to a solution of caesium chloride in five parts of water, warming enough to keep $CsClBr_2$ in solution, and passing chlorine in excess.

	Analysis gave	Calculated for $CsCl_2Br$.
Caesium	46·25	46·83
Chlorine	24·15	25·00
Bromine	26·05	28·17

[$CsCl_3$.]

Efforts to prepare this substance by passing chlorine into saturated aqueous solutions of caesium chloride cooled by a freezing-mixture did not succeed. It was noticable that the compound $Cl\ 5H_2O$ was not formed under these circumstances.

Other Trihalides.

Johnson's KI_3* is undoubtedly analogous to the caesium compounds. An investigation of this and other potassium trihalides as well as the corresponding rubidium compounds is now in progress in this laboratory, and an effort will be made to prepare similar compounds with still other metals.

The compound $KI_2(CN)$† and the body NH_4I_3, which Johnson describes‡ as very similar to KI_3, should be mentioned in this connection.

There have been described a great number of trihalides of both natural and artificial organic bases. These are mostly triiodides but there are among them a number of tribromides

* J. Chem. Soc., 1877, i, 249.

† Langlois, Ann. Chim. Phys., [III] lx, 220. ‡ J. Chem. Soc., 1878, 397.

and also mixed trihalides, especially of the type RCl_2I. These organic bodies* are evidently analogous to the caesium compounds under consideration, but since they have not been sufficiently studied to throw any light on the structure or crystalline form of trihalides in general, they will not be described in detail here.

Theoretical Considerations.

Thus far in this article the simplest possible formulæ have been used. The probable structure of the compounds will now be discussed.

The trihalides previously known have been usually considered as weakly combined addition-products. Mendelejeff,† for example, says that the instability with which I_2 unites with KI and $N(CH_3)_4I$ is analogous to the instability of many crystal-hydrates, e. g., $HCl.2H_2O$. It must be noticed that some of the caesium trihalides are very stable, but this fact is evidently due to the strong positive character of the metal, and, since others among them are comparatively unstable, it can have no important bearing on their structure.

Johnson‡ advances the formula K_2I_6 for potassium triiodide with no better reason than the existence of a higher iodide of mercury, HgI_6.§ This formula may be dismissed at once, for there is no more ground for it than for writing K_2I_2 because HgI_2 exists, and moreover if the caesium salts were Cs_2X_6 we should expect to find in the series such compounds as Cs_2Cl_5I, $Cs_2Cl_3I_3$, etc., none of which were discovered.

Since the members of the caesium series are crystallographically isomorphous they must all have the same structure, and, as has just been shown, no multiple of the formula CsX_3 is probable.

A possible explanation of the caesium trihalides may be made by supposing the metal to act trivalently, and the following arguments seem to favor this view:

1st. Caesium has the highest atomic weight of the alkali-metals, and it is a noticeable fact that, among the elements in general, those with higher atomic-weights in a group have the greater tendency to act with variable quantivalence. 2d. Caesium is univalent in its ordinary compounds, and, following

* See the following articles: Weltzien, Ann. Ch. Ph., xci, 33; xcix, 1. Müller, ibid., cviii, 5. Hubner, ibid., ccx, 368. Ladenburg, ibid., ccxvii, 122. Zinke and Lawson, ibid., ccxl, 123. Zinke and Artzberger, ibid., ccxlix, 366. Jörgensen, J. pr. Ch., II, vols. ii, iii, xiv and xv. Dafert, Monatshefte, iv, 496. Dittmar, Berichte, xviii, 1612. Ostermayer, ibid., xviii, 2298. Kamensky, ibid., xi, 1600. Tilden, J. Chem. Soc., xviii, 99. Hoogewerff and Dorp, Rec. Trav. Chim., iii, 361.

† "Grundlagen der Chemie," p. 563, foot-note 63.

‡ J. Chem. Soc., 1878, 183.

§ Jörgensen, J. pr. Ch., II, ii, 357.

the general rule, the next higher quantivalence should be three. 3rd. Caesium is in the same group as gold, in Mendelejeff's periodic system of the elements, and it is well known that this element acts univalently and trivalently.

On the other hand, the following arguments are in favor of considering the bodies double salts: 1st. The compounds IBr, ICl and BrCl are definite bodies and all the trihalides may be considered as molecular compounds of these, and also the molecules I_2 and Br_2, with normal halides. 2d. The fact that $CsBr_2I$ is more stable than $CsBrI_2$ and that $CsCl_2Br$ is more so than $CsClBr_2$, showing that the stability of these bodies does not entirely depend upon the volatility of the halogens contained in them, indicates that the halogen atoms have much influence on each other, and that at least two of them are probably bound together. A consideration of the fact that $CsCl_2I$ is a very stable body while $CsClI_2$ probably cannot be prepared leads to the same conclusion. 3d. It has been pointed out by Godeffroy* that the simple salts of caesium are as a rule more soluble than the corresponding rubidium and potassium salts, while with the double-salts the reverse is true. Work now in progress in this laboratory shows that the rubidium and potassium trihalides, as far as they have been investigated, increase in solubility towards potassium, hence, if the rule holds true, they must be double-salts. 4th. The new salt CsI.AgI,† an undoubted double-salt, shows a close relation to the trihalides in its system of crystallization, in the ratio of the two axes, which alone were determined, and in its cleavage.‡ The salt KI.AgI§ has been prepared, but it has not yet been procured in crystals fit for measurement. Work will be continued on this class of compounds.

* Berichte, ix, 1365.

† This was made by dissolving AgI in a concentrated, hot solution of CsI and cooling. It forms tufts of hair-like crystals, very seldom large enough to measure.

	Analysis gave	Calculated for CsI.AgI.
Silver	19·03	21·82
Iodine	50·91	51·32
Caesium	----	26·86

‡ CsI.AgI crystallizes in the orthorhombic system. It was obtained in long needles, not over ½ mm. in diameter and too small to show distinct end faces. A pinacoid and two other forms occur in the prismatic zone which correspond to $c(001)$, $g(012)$ and $d(011)$ of the trihalide series. Of these c and g are the best developed while d is very small. Five independent measurements of $c \wedge g$ gave values varying between 27° 29′ and 27° 44′, the average being 27° 36′ which gives the ratio $\bar{b} : \dot{c} = 1 : 1{\cdot}0456$. The crystals show a imperfect cleavage parallel to a (100) and probably a second parallel to c, but they were too small to allow of this being determined with certainty. Under the polarizing microscope they show parallel extinction.

§ Boullay, Ann. Chim. Phys., II, xxxiv, 377.

The evidence which has just been given points strongly towards considering the trihalides as double-salts. The considerations based on the axial relations of the crystals, which have been given in the crystallographic part of this article, also indicate that these bodies cannot be viewed as compounds of trivalent caesium, and, moreover, that a single halogen atom of highest atomic weight plays an important part in their structure. One view of the possible position of this peculiar atom may be that it is a trivalent atom united to the others in the manner indicated by the general formulæ $Cs-I<\overset{X}{X}$ and $Cs-Br<\overset{X}{X}$. This view may be objected to because the strongest halogen atom is not directly united to the caesium. The structure $Cs-X<\overset{X}{\underset{X}{\|}}$ is scarcely admissible in the compound CsI.AgI on account of the probable invariable univalence of silver.

Another view of the position of the peculiar iodine or bromine atom may be based upon the idea, so ably advocated by Remsen,* that a bivalent group of two halogen atoms acts the same part in double halides that oxygen takes in ordinary oxygen salts. Supposing that a halogen atom of highest atomic weight is linked to the caesium atom by means of the other two halogen atoms, acting as a bivalent group, the trihalides have the following formulæ:

Cs—(II)—I	Cs—(BrBr)—Br
Cs—(BrI)—I	Cs—(ClBr)—Br
Cs—(BrBr)—I	Cs—(ClCl)—Br
Cs—(ClBr)—I	
Cs—(ClCl)—I	
[Cs—(ClI)—I]	[Cs—(ClCl)—Cl]

These formulæ allow the supposition that the most negative halogen atom is in direct union with the caesium. They are consistent with the view that there are two symmetrical series of compounds, one with an iodine atom, the other with a bromine atom in a special position. On these grounds they seem quite plausible.

Assuming that the structure of the trihalides is represented by the above formulæ, a comparison of their relative stability leads to the view that the linking group of two halogen atoms causes greater stability when composed of like atoms than when these atoms differ. The groups (II) (BrBr) and (ClCl) occur in the comparatively stable compounds, while (ClBr) is in the most unstable body of the "bromine series," (BrI) is in

* On the Nature and Structure of Double Halides, Am. Chem. Jour., xi, 291.

the least stable one of the "iodine series" and the compound which should contain (ClI), with the least closely related halogens, could not be prepared. There is a possible exception in the body Cs−(ClBr)−I, for it has not been noticed that the stability of this varies to any marked extent from Cs−(ClCl)−I. The same view of the effect of the identity of the linking halogen atoms will probably apply to all double halides, for it is certain that very few of these containing different halogens are known, although this may be partly due to the fact that mixed double halides have not been sufficiently studied. An investigation of the double halides of caesium and mercury, now in progress, indicates that the generalization will apply in this case. Whatever may be the true structure of double halides, this influence of the identity of the halogens in the combining simple salts probably depends upon the same broad chemical law which causes, for example, two oxides or two sulphides to combine more readily than an oxide and a sulphide of the same elements, and which causes sulphates to combine with other sulphates more readily than they combine with nitrates and other dissimilar salts.

The present communication may be considered as preliminary to a wider study of polyhalides and double halogen salts. It is hoped that other series, studied chemically and crystallographically, may give valuable results.

Sheffield Scientific School, December, 1891.

ART. V.—*The Law of Elastic Lengthening;** by J. O. THOMPSON, Haverford College.

IN the theory of elasticity the assumption is usually made that the lengthening of an elastic rod or wire is directly proportional to the stretching weight. Moreover experimental results have apparently justified this assumption in all cases where the lengthening was within the so-called limit of elasticity. Hooke† was the first to formulate this as a law, and his assertion "*ut tensio sic vis*," although occasionally questioned seems to have stood the test of experiment up to the present time. Wertheim‡ in his well-known investigations concerning the elasticity of the metals, and later Edlund§ in his measure-

*Translation made by the author for this Journal of a paper which appeared in Wiedemann's Annalen, vol. xliv, No. 11, 1891.

†R. Hooke, Lectures and Collections, London, 1679.

‡Wertheim, Pogg. Ann., Ergänz, ii, (1848), p. 1.

§Edlund, Pogg. Ann., cxiv, (1861), p. 1, and cxxvi, (1865), p. 539.

ments of the thermal effects produced by the stretching of wires find no inaccuracy in the law. Neither did Morin,* although the distance between the upper and lower marks on his wires amounted to 21 m.

Miller† too endeavors to prove that the elastic lengthening is proportional to the force. As far as I am aware, the old law has generally been regarded as axiomatic, and no one has ever made the attempt to replace it by a new one.

At the time of some experiments here made by Mr. Stradling this subject came up for discussion, and Prof. F. Kohlrausch invited me to investigate it in a series of careful experiments. In this place I desire to express my sincerest thanks to my honored teacher, Prof. Kohlrausch, for his advice and help in the course of these investigations.

In the first place it should be noticed that there is no good *a priori* reason why Hooke's law should be strictly true. When one examines the case closely it seems highly probable that deviations from the law should appear. When a wire is subjected to a tension the relative positions and distances of its molecules are altered, its thermal state is changed, and it becomes in these respects a new body. Accordingly that there should be in one and the same body a definite relation between the modulus of elasticity and the amount of deformation ought to occasion no surprise.

Since the experiments of others have amply proved that deviations from the old law of lengthening, if any really exist, must be very small, it is evident at the outset that the measurements, in order to detect these deviations, must possess a high degree of accuracy. The following experimental conditions must accordingly be secured: The wire must be long and free from all curvature. The temperature of the place where the experiments are made must remain approximately constant during an experiment. Further, account must be taken of several secondary phenomena the most important of which are the thermal effects due to the changing volume of the wire, and the elastic after-effect. The influence of these secondary phenomena will later be separately discussed.

The wires made especially for these experiments by Herr Obermaier of Nürnberg, gave me the first of the above mentioned conditions. The tower of the Physical Institute of the University of Strassburg, permitted the use of wires of the requisite length; and, since it was situated on the north side of the building, it possessed such a uniform temperature that

* Morin, Comptes Rendus, liv, (1862), p. 235.

† Miller, Aus d. Sitzungsber. d. math-phys. Classe der k. bayer. Akd. d. Wiss, 1882, Heft 4.

the total change in an entire forenoon amounted usually to less than half a Celsius degree. The length of the wires used was about 23 m.

In order to determine the mean temperature of the tower at any time, as well as the changes in the temperature, I used at first six thermometers hung at regular intervals in the tower. Afterwards at the suggestion of Prof. Kohlrausch I used in place of the six thermometers a fine brass wire 23 m. long, bearing a constant weight, and running parallel with the main-wire, the wire on which the measurements were made.

Since this thermometer-wire was only 9 cm. distant from the main-wire, and both were equidistant from cathetometer I, I was able, without changing the focus of the telescope, to observe the mark on the thermometer-wire and to determine the temperature accurately to the fortieth of a degree.

Description of Apparatus.

In the tower of the Institute are four solid brick piers, three of which terminate within the tower near the top. A large square beam 25 cm. thick was laid across two diagonally opposite piers, and this furnished an inflexible support for the upper end of the wire. A smaller beam was laid parallel with the larger, and on this was mounted a microscope focused on the upper mark on the wire. The larger beam rested on iron feet which were so adjusted that the whole arrangement stood absolutely firm. A movable cross-wire in the eye-piece of the microscope enabled one to measure a displacement of the mark of 0·005 mm. Since a weight of 70 kg. on the middle of the beam produced a sinking of only 0·03 mm. and since the heaviest weight used in any of my experiments was 18 kg. we may regard the upper mark as constant. Still to avoid all uncertainty the position of the mark was often noted and found to be unchanged.

At the lower end of the wire the following arrangement was used: Two cathetometers were mounted on the same stone block, one for the purpose of noting the position of the mark when no weight was on the pan, the other to note the exact point to which the mark was brought by any stretching weight. In order that a measurement might be made quickly, before the after-effect had time to make itself apparent, a damper immersed in glycerine was used. In this way one was enabled to make an accurate setting of the cathetometer within 10 sec. after the weight had been placed on the pan. To render impossible any friction between the damper and the sides of the surrounding vessel, the damper was fastend to the upper end of a light rectangular frame, to the lower end of which the pan

was attached. The frame thus surrounded the vessel without touching it or the board on which it stood. Without some such arrangement there would have been friction between the damper and the sides of the vessel whenever the weight failed to be exactly in the centre of the pan. Furthermore in order to check quickly all motion the wire was passed through a fine hole in a stiff piece of leather, and the side of the frame playing between the prongs of a fork was prevented from swinging through a large arc. The weights used had been carefully calibrated so that the average inaccuracy was less than $\frac{1}{20000}$.

At first I used as lower mark a fine diamond-mark on the wire itself or on a glass bead. Later I used instead a very fine arrow-point printed on paper, and this secured an accuracy of 0·005 mm. in the setting of the cathetometer. Since in some cases the observed stretching of the wire amounted to more than 66 mm. it is apparent that when one, besides all this, takes mean values of many series of measurements, it is possible to attain a high degree of accuracy.

Thermal Effects within the Wire.

It was easy to foresee that the chief difficulties in measuring the true elastic lengthening would be those arising from the elastic after-effect and from the thermal effects due to changes in the volume of the wire. These thermal effects according to theory and observation are proportional to the stretching weight, provided that the stretching is not carried beyond the so-called limit of elasticity. By means of special observations with a thermo-pile I was able to prove that in all my experiments there was no perceptible deviation from this proportionality, and this fact may be taken as evidence that in the experiments the stretching was not carried beyond the proper limit. These thermal effects were in every case of greater influence than the after-effect.

The formula given by Sir Wm. Thomson for the diminution in temperature Δt caused by the stretching weight Δp is

$$\Delta t = \frac{\mathrm{AT}\alpha}{wc}\,\Delta p$$

where A is the heat equivalent of the unit of work, T the absolute temperature, α the coefficient of linear thermal expansion, w the mass of the unit of length of the wire, and c the specific heat of the metal by constant pressure.

Clausius* derives the same equation and states that Joule has corroborated it experimentally. Still the investigation of Joule on this point aimed at and attained merely a rough proof

* Clausius, Mech. Wärmetheorie, 3 Aufl. I, p. 199, 1887.

of the above equation. Edlund* who later repeated these investigations with the best methods then known obtained thermal effects which were some 40 per cent smaller than the theoretical. Taking Edlund's results as a basis of calculation I found that in some cases these thermal effects could affect my measurements by as much as ·1 mm. The influence of the after-effect was much less, as will be shown later.

On account of the uncertainty in determining at any given instant the exact temperature of the wire after it had been stretched, I used in nearly all my experiments fine wires of from 0·2 mm. to 0·3 mm. diameter, for such wires assume quickly the temperature of the surrounding air. In order to estimate the rapidity with which the wire returned to its normal temperature after a weight had been placed upon the pan, I used a thermo-pile with mirror-galvanometer and scale. The thermo-pile consisted of two very fine wires, one of iron and the other of german-silver, fastened to the main-wire with the least possible amount of solder.

The sensitiveness as determined by the mean result of four experiments was 73 scale-divisions for 1° Celsius. In every case only the first deflection was recorded. The time of vibration of the needle was 6·5 sec. In determining the sensitiveness of the thermo-pile the junctions of the iron and german-silver wires with the galvanometer wires were immersed in petroleum of constant temperature, while the junctions with the main-wire, which were some 15 mm. apart, were immersed in a little rubber vessel containing distilled water. The temperatures of the water and of the petroleum were accurately determined, the circuit closed, and the deflection of the needle noted.

In measuring the thermal effects produced by the stretching of the wires the junctions of the thermo-pile wires with the main-wire were protected against air currents by a little cotton. Without this cotton the rapidity with which the wire near the junctions reassumed its normal temperature would have been even greater than it was. In a series of 8 consecutive determinations the mean position of rest of the galvanometer-needle was 635·7, the cooling of the brass wire occasioned by a weight of 1·5 kg. caused an average first deflection of 9·1 scale divisions toward the smaller numbers, and after 13 sec. or two vibrations the mean position of rest was 635·9.

A further proof of the rapid disappearance of the thermal effects is given by this very deflection of 9·1 scale-divisions. The first deflection was, as already mentioned, 73 scale-divisions for 1°. The cooling of the wire produced by the weight

* Edlund, Pogg. Ann., cxxvi, p. 557, 1865.

of 1·5 kg. amounted to 0·225° according to Edlund, and this difference of temperature, if it had remained constant during the time of the first deflection, would have produced a deflection of 16·4 scale-divisions instead of the actual 9·1. From this one can draw conclusions as to the rapidity of the disappearance of the thermal effects.

In all my experiments, even in extreme cases, I uniformly found that after a weight had been placed on the pan the needle would be deflected so as to indicate a certain cooling and then return with scarcely perceptible delay to its former position. Thus it was clear that after 13 sec. no visible trace of the cooling effect remained. If a difference of temperature of $\frac{1}{80}$°, enough to produce a contraction of 0·005 mm. in the length of the wire, had remained, the galvanometer would surely have indicated it.

The indications of the galvanometer were confirmed by noting the gradual contraction or lengthening of the wire immediately after unloading or loading the scale pan. In the first 10 or 12 sec. there would be a change of say 0·07 mm. in the length of the wire, and then in the following minute a further change of 0·01 mm. The first change one would naturally attribute chiefly to the thermal changes, the second to the after-effect. Since it is hardly possible in less than 12 sec. to place a weight on the pan and set the cathetometer with accuracy, it was to me a matter of indifference how much quicker the wire returned to its normal temperature.

Here it may be mentioned that Wertheim did not make his measurements until 5 or 10 min. after loading the pan. He waited, as he says, until the position of the mark became constant. In other words he did exactly what he should have avoided, he allowed his measurements to be affected by the most active part of the after-effect. Miller on the contrary went too far in the opposite direction and made measurements 2 sec. after stretching the wire. His results are obviously affected by temperature errors which he in a later article* seeks to correct.

The After-effect.

The complete calculation of the influence of the after-effect on my results would have required a large amount of time and trouble.

In the first place these phenomena have been studied chiefly in the cases of torsion and bending, and the laws of the after-effect in the case of stretching, at least as far as the metals are concerned, are unknown. Further in the present case we have

* Miller, Wied. Ann., xx, p. 94, 1883.

to deal with the superposition of different after-effects, and the problem becomes much more complex. The after-effect in the case of a strip of india-rubber is approximately proportional to the magnitude of the stretching.* Probably this applies to the metals as well, and if this is the case, the after-effect becomes of no account in the question we are discussing, provided the measurements are made always a definite time after the stretching of the wire. Moreover, since the after-effect in my experiments was invariably small I shall introduce in my results no correction for that factor.

Whenever the heaviest weights were used I set the cathetometer 13 sec. after placing the weight on the pan. This could be done by setting the cathetometer approximately beforehand. Careful measurements showed that this precaution was necessary only when the heaviest weights were used. In other cases it made no apparent difference whether the reading was made at the end of 13 sec. or a few seconds later. The measurements were made with rare exceptions at intervals of two minutes. In this time the after-effect following the release of the wire had almost entirely disappeared, as the results of two series of experiments given on pages 40 and 42 will show.

Still I wished to know exactly how soon this after-effect disappeared, and accordingly used the following plan: A fine flexible linen thread was tied to the bottom of the pan and then passed through a pulley beneath which was fastened to the floor. The thread was then made fast to the axle of a wheel, and thus by turning the wheel I could impart to the wire any desired tension.

In order to compare the influence of the after-effect with that of the thermal changes I proceeded as follows: By means of the thread a tension corresponding to a certain weight was imparted to the wire. The wire was kept stretched for about 13 sec. and then, by turning the wheel, released. During this process it was not necessary to remove my eye from the telescope. The wire came to rest without vibration in about one second, and a second later I had the telescope sighted on the mark. Then by means of the micrometer screw on cathetometer II, I measured the change in position of the mark in the following 11 sec., then the change from the 13th to the 30th second. By this time the mark had come back to its previous position. The results of the measurements with the brass wire are given in the following table:

* F. Kohlrausch, Pogg. Ann., clviii, p. 360, 1876.

Preceding Tension. kg.	Change from 2–13 sec. mm.	From 13–30. mm.	Total change. mm.
0·6	0·035	0·001	0·036
1·2	0·062	0·010	0·072
1·8	0·100	0·020	0·120

The figures in each column are mean values of 10, 20 and 8 measurements respectively. That the changes given in the second column come mostly from the thermal effects within the wire itself and not from the after-effect can be proved in the following way: If we insert in the equation which we have already mentioned in place of A the value $\frac{1}{682 \cdot 7}$ as obtained by Edlund we get

$$\Delta t = \frac{1}{682 \cdot 7} \frac{T \alpha}{w c} \Delta p.$$

In these experiments T=285°, α=0·000018, w=0·000528 kg. per m., and c=0·094. Consequently according to the equation Δt=0°·15 when Δp=1 kg. Since the wire was 22·7 m. long the change in its length for 1° was 0·409 mm., or 0·0614 mm. when Δt was 0°·15. Therefore on removing stretching weights of 0·6, 1·2 and 1·8 kg. the lengthenings of the wire caused by the evolution of heat in the first instant should be 0·037, 0·074 and 0·111 mm. respectively. These figures approximate those in the second column of the above table as closely as we could expect in an experiment of this kind.

From what has been said it is safe to conclude that the necessary correction on account of the after-effect is very small. The stretching of the wire caused by a weight of 1·2 kg. was 43·55 mm., and the change of 0·01 mm. which took place after the first 13 sec. is insignificant in comparison.

Method of Measurement.

The method followed in making all measurements was the same. After noting the position of the mark on the thermometer-wire the telescopes of both cathetometers were sighted on the mark on the main-wire, and careful readings were made. Then a weight of 0·2 kg. was put on the pan, the consequent lowering of the mark was quickly measured by cathetometer I, and then the weight was immediately removed.

Two minutes later any shifting of the zero-point was measured by means of the micrometer screw of cathetometer II, and then the same process was repeated with a weight of 0·4 kg. In some cases the weight was increased to as much as 1·8 kg.

By means of the micrometer screw of cathetometer II. I could measure the shifting of the zero-point accurately to 0·005 mm. In this direction only an extremely small inaccuracy was possible because almost without exception the gradual lowering of the zero-point, in consequence of rising temperature and other causes, allowed the screw to be turned always in the same direction.

At the end of each series of observations the zero-point was again noted by both cathetometers, and the displacement measured. The difference in the results given by the two instruments was on an average less than 0·005 mm. Finally, in order to eliminate the influence of any change of temperature in the tower, the position of the mark on the thermometer-wire was again noted.

Experiments with Brass Wire.

As an example of the process just described I give the following series of measurements:

Apr. 25, 10h. 5m. Thermometer-wire, 540·71
Temperature, 9°·5

Added weight. kg.	Time. h. m.	Cath. I. mm.	Cath. II. mm.	Lengthening. mm.
0	10 8	548·96		
0·2	9	41·84	0·15	7·12
0·4	11	34·70	"	14·26
0·6	13	27·46	"	21·50
0·8	15	20·18	"	28·78
1·0	17	12·81	0·14	36·14
1·2	19	5·39	"	43·56
1·4	21	497·885	"	51·065
1·6	23	90·26	0·135	58·685
1·8	25	82·60	0·125	66·335
·0	27	548·92	0·105	

10 h. 30 m. Thermometer-wire, 540·68

The lowering of the zero-point during these measurements was 0·04 mm. according to cathetometer I, and 0·045 mm. according to cathetometer II. The thermometer-wire, which was just like the main-wire, lengthened by 0·03 mm. during this time. The rise in temperature was accordingly $\frac{3}{5}$°, about twice the ordinary rise. The above table indicates, as already shown by the table on p. 39, that with an added weight of 1·8 kg. the after-effect begins to be noticeable. The lengthening produced by this weight I have given, but not taken into account in my later calculations. The initial load plus 1·8 kg. amounted to nearly half the breaking weight.

Table of 10 Series of Measurements.

Kg.											Mean mm.
0·2	7·10	·13	·12	·11	·105	·12	·11	·11	·12	·09	7·111
0·4	14·25	·265	·26	·28	·285	·27	·265	·27	·28	·27	14·269
0·6	21·47	·50	·50	·50	·485	·495	·49	·475	·49	·49	21·489
0·8	28·76	·775	·78	·77	·75	·785	·77	·77	·79	·77	28·772
1·0	36·11	·125	·14	·145	·115	·13	·13	·11	·12	·12	36·124
1·2	43·53	·57	·56	·55	·555	*	·57	·55	·545	·56	43·554
1·4	51·05	·07	·065	·07	·065	·06	·065	·09	·055	·08	51·067
1·6	58·66	·71	·685	·71	·66	·69	·675	·68	·69	·675	58·683
1·8	66·33	·355	·335	·36	·32	·35	·31	·32	·34	·32	66·334

Ten additional series of measurements were made. The mean values derived from the 20 series are given in the following table under *x observed*.

p.	*x* observed.	*x* calculated.	Observed-calc.
0·2 kg.	7·111	·110	+0·001
0·4	14·272	·271	+ 1
0·6	21·488	·488	± 0
0·8	28·770	·770	± 0
1·0	36·119	·122	− 3
1·2	43·554	·554	± 0
1·4	51·076	·071	+ 5
1·6	58·679	·681	− 2
1·8	66·341	----	----

Mean temperature, 9°.
Cross-section of wire, 0·0627 mm.^{2}
Length of wire, 22700 mm.
Specific gravity of wire, 8·42
Initial load, 0·665 kg.
p = added weight, and x = lengthening.

Expressing the result of the measurements by an equation of the form

$$x = ap + bp^2 + cp^3$$

I obtained the equation

$$x = 35{\cdot}4385\ p + 0{\cdot}5353\ p^2 + 0{\cdot}1487\ p^3$$

The calculation of the most probable values of the constants a, b and c, was effected in this case, as in all the other cases, by means of the method of least squares. The mean error of the individual measurements calculated from the 10 lengthenings produced by a weight of 1·4 kg. and given in the table on p. 41, is 0·011 mm. and the probable error of the mean result is 0·0024 mm. Two minutes after the weighting and release of the wire the mean lowering of the zero-point was 0·009 mm.

* No measurement was made. If I had waited for the mark to come to rest the after-effect would have been noticeable.

The initial load, consisting of frame, scale-pan, damper, and half the weight of the wire itself, amounted to ·665 kg. This was probably twice as much as was really necessary to keep the wire straight. In later measurements a lighter frame was used.

Experiments with Copper Wire.

The following is one of ten series of measurements made May 23rd.

Time 4 h. 7 m. Thermometer-wire 540·70

Added weight. kg.	Time. h. m.	Cath. I. mm.	Cath. II. mm.	Lengthening. mm.
0	4 9	554·82		
0·2	10	49·29	0·15	5·53
0·4	12	43·73	"	11·09
0·6	14	38·14	"	16·68
0·8	16	32·51	"	22·31
1·0	18	26·84	0·14	27·97
1·2	20	21·14	0·13	33·66
0	22	554·795	0·12	

Lowering of zero-point, 0·025 0·03

4 h. 27 m. Thermometer-wire 540·70

At 4 h. 33 m., the beginning of the next series of observations, the zero-point had risen 0·015 mm. on account of the after-effect. This was generally the case between any two series. The influence of the after-effect, although rather more marked here than in the case of the other metals experimented upon, was not enough to affect the value of the measurements.

On this day the temperature was remarkably constant. The total steady lengthening of the thermometer-wire between 2 h. 50 m. and 5 h. 23 m. amounted to only 0·02 mm.

The following table gives the results of eight successive measurements made with the copper wire May 23rd.

p. kg.									Mean mm.
0·2	5·535	·535	·54	·53	·53	·53	·53	·535	5·533
0·4	11·085	·08	·10	·085	·09	·09	·09	·095	11·090
0·6	16·675	·675	·685	·685	·685	·68	·67	·68	16·680
0·8	22·31	·305	·31	·31	·30	·31	·31	·31	22·308
1·0	27·97	·94	·98	·985	·95	·97	·94	·945	27·960
1·2	33·665	·65	·72	·685	·67	·66	·64	·62	33·664

The following table gives the mean values derived from 16 series of measurements with copper wire.

p. kg.	x observed. mm.	x calculated. mm.	Observed-calc. mm.
0·2	5·531	·529	+ 0·002
0·4	11·084	·086	− 2
0·6	16·671	·673	− 2
0·8	22·298	·294	+ 4
1·0	27·949	·951	− 2
1·2	33·646	·646	± 0

Mean temperature, 13°·5
Cross-section of wire, 0·0641 mm.²
Length of wire, 22690 mm.
Specific gravity of wire, 8·99
Initial load 0·192 kg.

The figures of the third column were calculated according to the equation

$$x = 27{\cdot}578\,p + 0{\cdot}3193\,p^2 + 0{\cdot}0538\,p^3.$$

The initial load was 0·192 kg. Measurements showed that 0·15 kg. sufficed to hold the wire straight, while 0·10 kg. was insufficient.

Experiments with Steel Wire.

The following table gives the mean result of 20 series of measurements.

p. kg.	x observed. mm.	x calculated. mm.	Observed-calc. mm.
0·2	7·078	·077	+ 0·001
0·4	14·196	·197	− 1
0·6	21·358	·358	± 0
0·8	28·558	·558	± 0
1·0	35·792	·793	− 1

Mean temperature, 13°
Cross-section of wire, 0·03263 mm.²
Length of wire, 22700 mm.
Specific gravity of wire, 7·74
Initial load, 0·491 kg.

The figures in the third column were calculated according to the equation

$$x = 35{\cdot}2725\,p + 0{\cdot}5725\,p^2 - 0{\cdot}0525\,p^3$$

An evidence of the insignificance of the after-effect may be seen in the fact that in ten successive series of measurements the lengthening caused by the maximum load deviated in no case more than ·0225 mm. from the mean. Two minutes after the release of the wire the mean position of the zero-point was ·01 mm. lower than immediately before this maximum load was put on the pan.

Experiments with Silver Wire.

The following table gives the mean result of eight series of measurements.

p. kg.	x observed. mm.	x calculated. mm.	Observed-calc. mm.
0·2	7·898	·896	+ 0·002
0·4	15·820	·822	− 2
0·6	23·775	·776	− 1
0·8	31·758	·756	+ 2
1·0	39·762	·762	± 0

Mean temperature, 14°
Cross-section of wire, 0·0687 mm.²
Length of wire, 22690 mm.
Specific gravity of wire, 10·00
Initial load, 0·593 kg.

The figures in the third column were calculated according to the equation

$$x = 39{\cdot}4030\, p + 0{\cdot}3905\, p^2 - 0{\cdot}0313\, p^3$$

This wire was not so free from curves as the others, and consequently it was necessary to begin with a comparatively heavy initial load.

The influence of the after-effect was as a rule so slight that it could not be measured. After each release of the wire the mark returned quickly to the zero-point, and the sinking of the zero-point was explained almost entirely by the gradual rise in temperature in the tower.

Calculation of the True Modulus of Elasticity.

From the results given above it follows that the modulus of elasticity is not a constant, but in every case a function of the tension. From the equation

$$x = ap + bp^2 + cp^3$$

which gives the relation between the elastic lengthening and the stretching weight we obtain

$$\frac{dx}{dp} = a + 2bp + 3cp^2$$

and with the help of this latter equation we can compute the modulus for any tension whatever.

The almost perfect agreement between the observed and calculated values of x makes it extremely probable that, inasmuch as the initial load was slight, we may extend the application of this equation backwards to an initial load of zero.

Thus we shall be in a position to determine the true modulus of elasticity, the modulus of the body before it has been subjected to any deformation whatever.

In order to determine this true modulus we may proceed as follows:

Let $X_\circ$ be the lengthening caused by the initial load $P_\circ$*
" X " " " " " total weight $P^\circ + p$

Then the observed lengthening $x = X - X_\circ$

$$\text{Let } X = \alpha P + \beta P^2 + \gamma P^3 \quad (1)$$
$$\text{and } X_\circ = \alpha P_\circ + \beta P_\circ{}^2 + \gamma P_\circ{}^3 \quad (2)$$

Equation (2) subtracted from (1) gives

$$x = (-\alpha P_\circ - \beta P_\circ{}^2 - \gamma P_\circ{}^3) + \alpha P + \beta P^2 + \gamma P^3 \quad (3)$$

The results of the measurements were given in the following form

$$x = a(P - P_\circ) + b(P - P_\circ)^2 + c(P - P_\circ)^3$$
$$= (-aP_\circ + bP_\circ{}^2 - cP_\circ{}^3) + (a - 2bP_\circ + 3cP_\circ{}^2)P + (b - 3cP_\circ)P^2 + cP^3 \quad (4)$$

Equating the coefficients of like powers of the variable P in the two expressions for x in (3) and (4) we obtain

$$\alpha = a - 2bP_\circ + 3cP_\circ{}^2$$
$$\beta = b - 3cP_\circ$$
$$\gamma = c$$

Equation (1) which gives the relation between elastic lengthening and stretching weight when one begins with an initial load zero becomes in the case of the steel wire for instance

$$X = 34{\cdot}672P + 0{\cdot}6498P^2 - 0{\cdot}0525P^3$$

and $$\left(\frac{dX}{dP}\right)_{P=0} = 34{\cdot}672$$

With an infinitesimal stretching weight the formula for the modulus of elasticity is

$$E = \frac{l}{q} \cdot \frac{dP}{dX}$$

where l is the length and q the cross-section of the wire. Therefore in this case

$$E = \frac{22683}{0{\cdot}03263} \cdot \frac{1}{34{\cdot}672} = 20050$$

The length of the unstretched wire l can be found with the help of equation (2).

*$P_\circ$ represents the weight of the frame with pan and damper, increased by half the weight of the wire.

The equations giving the relation between elastic lengthening and stretching weight when one begins with zero load are as follows:

Steel..... $X=34{\cdot}672P+0{\cdot}6498P^2-0{\cdot}0525P^3$
Brass ..... $X=34{\cdot}924P+0{\cdot}2386P^2+0{\cdot}1487P^3$
Silver ..... $X=38{\cdot}907P+0{\cdot}4462P^2-0{\cdot}0313P^3$
Copper ..... $X=27{\cdot}461P+0{\cdot}2883P^2+0{\cdot}0538P^3$

The specific gravities, cross-sections, and moduli calculated by the above method are given in the following table.

	Sp. Gr.	Cross-section.	True Modulus.	Modulus I.	Modulus II.
Steel	7·74	0·03263	20050	19430	19230
Brass ...	8·42	0·0627	10370	9820	9450
Silver ...	10·00	0·0687	8490	8300	8250
Copper..	8·99	0·0641	12890	12620	12420

In order to show still more clearly the dependence of the modulus on the tension I add two more columns. The next to the last column gives the modulus which one would obtain if only the lengthening caused by the maximum added load were taken into account. The last column, the modulus which would be obtained if only the increase of lengthening caused by the last 0·2 kg. should be made the basis of calculation. As will be seen, the true modulus of elasticity of the brass wire is nearly 10 per cent greater than the one given in the last column.

Influence of Contraction of Cross-Section.

When a wire is stretched so that each unit of length increases by δ, the cross-section becomes $Q_o(1-2\mu\delta)$ if Q_o is the original cross-section. Theoretically μ can have in different bodies any value between the limits 0 and $\frac{1}{2}$. Supposing that in the case of steel $\mu=0{\cdot}294$, as Kirchhoff states, we find that for a weight of 1 kg. $\delta=35{\cdot}8\div 22700=0{\cdot}0016$ and the cross-section is accordingly $Q_o(1-0{\cdot}00094)$. If we wished to refer the modulus of elasticity in this case to this diminished cross-section, the coefficients of our equations would suffer a perceptible change. But it is not customary to do this, and we shall refer the modulus to the condition of the unstretched wire. Further it should be noticed that the value of μ is not definitely known; in fact, there is ground for believing that in one and the same body it is a variable quantity.

Larger Wires.

In order to be perfectly sure that the phenomena which I have described were not confined to fine wires, I made careful measurements with larger wires. The loads placed on these

were gradually increased to a maximum of 18 kg. and without exception the results obtained were similar to those which I have reported. The reasons however why I preferred to use fine wires are first, because in these the thermal effects vanish more rapidly, and second, because the loading and unloading can be done in shorter time, and thus the after-effect is more completely eliminated.

Earlier Investigators.

Since these investigations have yielded results which are at variance with those hitherto obtained, it is desirable to search for an explanation of the discrepancy. It is evident that the presence of curves and bends in the wire would give to $\frac{x}{p}$ too large a value which would gradually decrease as the wire grew straight. This circumstance would account for Stradling's remark* according to which the modulus of elasticity would increase with the tension, and is the probable explanation of the fact that Wertheim† in the case of annealed platinum finds the modulus increasing with the weight. Further the almost universal result obtained by other investigators, namely that $\frac{x}{p}$ has a constant value, can be explained in the very same way. The diminution of the modulus alone considered would make $\frac{x}{p}$ larger, while the gradual straightening of the wire would tend to make it smaller. The combination of these two factors could easily lead to the conclusion that within the limits of errors of observation $\frac{x}{p}$ has a constant value.

Discussion of Results.

Whatever the nature of elastic force may be, whether it is an essential property of matter, or a derived property which can be accounted for by the rotation of atoms, the fact was established by Wertheim that between the elasticity of a body and its density there exists an intimate relation. Conclusion I of his investigation is as follows:‡ "The coefficient of elasticity is not a constant for one and the same metal. All circumstances which increase the density make it larger, and conversely." These words justify a deduction which Wertheim

* Stradling, Wied. Ann., xli, p. 332, 1890.
† Wertheim, Pogg. Ann. Ergänz., ii, p. 46, 1848.
‡ Wertheim, l. c. p. 69.

himself seems not to have made, for conclusion VII shows that he did not look for any change in the modulus of elasticity until the density of the body had been permanently altered. Wertheim proved that the density of a wire before an experiment differs very slightly from its density after it has been broken by its load. He therefore concludes that in one and the same wire, even when it is in different conditions of equilibrium, the modulus of elasticity can vary only a very little.

But it should be kept in mind that, although on account of the contraction of cross-section the change in density is slight, the mean molecular distance in the direction in which the tension is exerted probably increases by a very considerable amount. And it is probable that the variability of the modulus of elasticity should be attributed not so much to the alteration in density of the body considered as a whole, as to this change of mean molecular distance in the direction of the tension. According to Wertheim's own assumption we should have in one and the same metal

$$\text{Mod. of elasticity} \times a^7 = \text{constant},$$

where a represents the mean molecular distance. According to this any change in a would produce in the modulus a change proportionally seven times as great, and this in the case of the stretching of a wire can become very noticeable. According to my own measurements to be sure a much higher power than the seventh must be assumed in the formula.

If it is universally true that an increase of the mean molecular distance causes a diminution of the modulus of elasticity according to a definite law, then in those metals which have the largest coefficients of thermal expansion the decrease of the modulus of elasticity with the temperature ought to be most rapid. That this is actually the case has been already mentioned by Miller* and Katzenelsohn.† A further deduction would be that since by higher temperatures the coefficient of thermal expansion grows larger, the modulus should here decrease more rapidly than by lower temperatures. That this is also true has been proved by the measurements of Kohlrausch and Loomis‡ and Pisati.§

Further if a substance like india rubber has a negative coefficient of thermal expansion, it would follow from our principle that as the temperature increases the modulus should increase too. Just such an increase in the modulus of elasticity

* Miller, Wied. Beibl., xi, p. 211, 1887.
† Katzenelsohn, Wied. Beibl., xii, p. 307, 1888.
‡ F. Kohlrausch and Loomis, Pogg. Ann., cxli, p. 498, 1870.
§ Pisati, Wied. Beibl., i, p. 305, 1877.

of india rubber has been observed by Miller* *These facts and the results of my experiments justify the conclusion that in every case the modulus of elasticity of a body is a function of the molecular distance, and that every agency, whether it be heat or mechanical force, which increases this molecular distance, produces a diminution of the modulus of elasticity.*

This relation which is enunciated here for the first time as a general law has, as far as I am aware, no exception which cannot be explained by the necessary errors of observation.

It is interesting to notice that in many instances the theory of probabilities is able to deduce from the measurements of Wertheim results similar to mine. The following values for the moduli of pure gold (Wertheim, l. c. p. 30), and pure silver (p. 45) show on their face an evident diminution as the stretching weight increases.

kg.	gold.	silver.
3	7030	
4	6391	
5	5021	7701
6	5492	7578
7	5340	6476
8	5291	7555
9	4972	7213
10	5140	7123

In other cases, for instance in the measurements made with copper (p. 35) and silver (p. 31) where consecutive values of the modulus differ by as much as 10 per cent it is necessary to apply the theory of probabilities.

In the previously mentioned measurements with annealed platinum the opposite tendency can probably be explained by curvature of the wire.

Whether in the method of flexure it is possible to detect a dependence of the modulus on the amount of the load I have not had time to investigate. Since however the compression on one side of the neutral layer is equal to the extension on the other, and consequently the density remains either exactly or very nearly the same, it is probable that in this case no change in the modulus of elasticity could be observed.

A number of relations and applications of this true law of elastic lengthening to other physical laws, and other phenomena observed in the course of my experiments, I shall discuss at some future time.

* Miller, l. c.

Conclusions.

I. The generally accepted law of elastic lengthening $x=aP$, according to which the lengthening x is proportional to the stretching weight P, is only an approximation.

II. The relation between elastic extension and stretching weight can be expressed by an equation of the following form:

$$X=\alpha P+\beta P^2+\gamma P^3$$

III. The modulus of elasticity of the undeformed body can be calculated with the help of the equation

$$\left(\frac{dX}{dP}\right)_{P=0}=\alpha$$

IV. The true moduli of elasticity calculated in this way may be as much as 10 per cent larger than those determined in the ordinary way. Consequently it will be necessary to recalculate physical constants which depend on the modulus of elasticity.

Haverford College Laboratory.

ART. VI.—*A Method for the Quantitative Separation of Strontium from Calcium by the Action of Amyl Alcohol on the Nitrates;* by P. E. BROWNING.

[Contributions from the Kent Chemical Laboratory of Yale College—XI.]

AT the suggestions of Prof. F. A. Gooch, and following the general mode of procedure laid down in his paper* upon the separation of sodium and potassium from lithium by the action of amyl alcohol on the chlorides, I undertook a series of experiments looking toward the separation of strontium from calcium by the action of amyl alcohol on the nitrates. On boiling several portions of the so-called chemically pure calcium and strontium nitrates with amyl alcohol, nearly complete solubility was observed in case of the calcium salt, while corresponding insolubility seemed to be characteristic of the strontium salt, and these results seemed to warrant proceeding with the work.

For the quantitative tests to be described standard solutions of specially purified strontium and calcium nitrates were prepared. In general the preparation was effected by precipitating a soluble salt of either element with ammonium carbonate in the presence of ammonium chloride, washing thoroughly with boiling water, dissolving in the least possible amount of

* Amer. Chem. Jour., vol. ix, p. 33.

nitric acid, and making up to measure. In the earlier experiments other methods of purification were used, such as the precipitation of the strontium nitrate by alcohol, and in case of the calcium salt the preparation of the nitrate from the carbonate precipitated by ammonium carbonate from a solution of calcium sulphate. The method first described, however, gave satisfactory results, the spectroscope failing to show in the product thus obtained any trace of intermixture of calcium and strontium salts, or the presence of any other appreciable impurity. In the determination of the standards of these solutions definite amounts were drawn off from burettes into counterpoised beakers or crucibles (according as the method of determination was by precipitation or evaporation) and weighed as a check on the burette reading. The strontium nitrate in each portion was converted into the sulphate either by precipitation in the presence of alcohol, or by evaporating and igniting, these methods yielding results closely agreeing. The calcium was determined by evaporation with sulphuric acid. The first series of experiments was directed toward an investigation of the action of amyl alcohol upon strontium nitrate alone. Accordingly several amounts of the strontium salt were measured from a burette into counterpoised Bohemian beakers of about 100 cm^3 capacity, and weighed. The water was then evaporated over a water bath, and the dry salts dissolved in a few drops of water and boiled with 30 cm^3 of amyl alcohol, that amount being determined upon for convenience. Care should be taken not to add more than the necessary amount of water to dissolve the salt, inasmuch as the presence of much water delays the process (it being necessary to expel all the water before the amyl alcohol can do its work) and tends to cause spattering due to the superheating of the water and consequent sudden generation of steam under the alcohol. It has been my experience that in the presence of a few drops of water the boiling goes on quietly, the water escaping easily through the amyl alcohol, so that in the course of a few minutes the alcohol reaches its normal boiling temperature (128°–130° C.) In order that the inflammable fumes of the alcohol might not reach the flame during the boiling the beaker was placed upon a piece of asbestos board about 15 cm. square. When the temperature of the alcohol reached its normal boiling point (128°—130° C.), as shown by a thermometer, the beaker was removed and the strontium nitrate filtered off upon an asbestos felt in a perforated platinum crucible, the crucible and felt having been previously dried and weighed.

The filtration was carried on under gentle pressure, the filtrate being received in a beaker standing under a bell jar upon a ground glass plate. The last traces of strontium nitrate

were removed from the beaker by washing with small amounts of previously boiled amyl alcohol contained in a wash-bottle the mouthpiece of which consisted of a small chloride of calcium tube passing through the stopper and drawn out and plugged at the lower end with cotton to exclude particles of the calcium salt from the alcohol. By this device the introduction of moisture into the amyl alcohol was guarded against. The crucible containing the strontium nitrate was placed in an air bath and heated to 150° C. to drive off all amyl alcohol, and weighed. A constant weight was obtained uniformly in one treatment. Series I contains the results of these experiments, the strontium being calculated as oxide.

SERIES I.

(1) SrO taken 0·1229 grm.	SrO found 0·1220 grm.	Loss 0·0009 grm.
(2) " " 0·1231 "	" " 0·1221 "	" 0·0010 "
(3) " " 0·1230 "	" " 0·1219 "	" 0·0011 "
(4) " " 0·1227 "	" " 0·1213 "	" 0·0014 "

These results suggested a possible solubility of the strontium salt, and, accordingly, experiments were made to test this point. Amounts of strontium nitrate closely agreeing with those above were taken and treated in the same manner. The filtrates amounting, without the washings, to about 25 cm^3 were evaporated to dryness. The residue was ignited to burn off organic matter from the amyl alcohol, treated with sulphuric acid, heated to low redness, and weighed. In two cases the residue of strontium sulphate was found to contain of the oxide respectively 0·0009 grm. and 0·0010 grm. As will be seen the solubility of the strontium nitrate averages about 0·0010 grm. of the oxide to 30 cm^3 of amyl alcohol used. The exact extent of this solubility depends, of course, upon the amount of amyl alcohol remaining after boiling; and, since the source of heat is removed as soon as the normal boiling temperature of the alcohol is reached, very little decrease in the volume of the previously boiled alcohol results. On measuring the amounts of the alcohol remaining in several experiments I found them to approximate closely to 25 cm^3. It seemed justifiable, therefore, to add as a correction to the apparent amount of strontium oxide found 0·0010 grm. for every 25 $cm.^3$ of amyl alcohol remaining, or for every 30 $cm.^3$ originally taken. Experiments were also made to determine whether the strontium nitrate might have been at all broken down in the process of boiling and heating so that some strontium might be present in the final residue in the form of oxide or nitrite. In two of these experiments portions of strontium nitrate left by the treatment with amyl alcohol were dissolved, precipitated as the

sulphate and weighed as such, and the results of these experiments (5 and 6) go to show that the composition of the strontium nitrate is not appreciably changed in the process of separation and drying. In certain other experiments directed to the same end, the residues of the process of separation were, after weighing and drying, treated with a drop of nitric acid, and again dried at 150° C. and weighed. These tests (7) and (8) confirm the indications of the previous experiments. Finally a third experiment was made upon strontium nitrate dried at 150° C. to see what decomposition might result by heating to temperatures somewhat higher than 150° C.—the temperature at which the residues of the previous experiments had been dried. The result shows that the loss in the twenty-five degrees above 150° C. is exceedingly slight.

(5)	$Sr(NO_3)_2$ calculated as SrO	0·1219 grm.
	The same dissolved and precipitated as $SrSO_4$ calculated as SrO	0·1219 grm.
(6)	$Sr(NO_3)_2$ calculated as SrO	0·1213 grm.
	The same dissolved and precipitated as $SrSO_4$ calculated as SrO	0·1214 grm.
(7)	$Sr(NO_3)_2$ calculated as SrO	0·1228 grm.
	The same dried at 150° C. after adding a drop of HNO_3	0·1228 grm.
(8)	$Sr(NO_3)_2$ calculated as SrO	0·1239 grm.
	The same dried at 150° C. after adding a drop of HNO_3	0·1239 grm.
(9)	Weight of $Sr(NO_3)_2$ dried at 150° C.	0·2482 grm.
	Weight of the same portion dried at 165° C.	0·2480 grm.
	Weight of the same portion dried at 175° C.	0·2478 grm.

When calcium nitrate was treated in a similar manner by boiling with amyl alcohol the mass of the salt dissolved, but minute portions separated out on the bottom or sides of the beaker. Such residues were, however, very small and on weighing were found not to exceed 0·0003 grm. or 0·0004 grm. of the oxide. In several instances this insoluble residue was washed thoroughly with ethyl alcohol, dissolved in water, tested before the spectroscope and found to give the characteristic calcium spectrum. All experience pointed to the fact that the formations of the residue was due to some very slight change of composition of the calcium nitrate. On one or two occasions the acidified solution of the residue appeared to reduce a drop of an extremely dilute solution of potassium permanganate, and this action suggested the presence of a nitrite. Treatment of this residue with nitric acid and subsequent evaporation of the excess of acid failed, however, to leave the calcium salt in a condition to be dissolved by amyl alcohol.

It is possible, therefore, that the real cause of insolubility is to be sought in the oxidation of the amyl alcohol and consequent formation of an organic acid, and, subsequently, of the corresponding calcium salt, but the amounts of the residue were so extremely small that it was not practicable to solve this question, at once, exactly and satisfactorily without directing attention too far from the main issue. Moreover, the error introduced by this peculiar behavior of the calcium salt proved to be insignificant in its effects upon the quantitative determination of the calcium, and accordingly, it was disregarded in the subsequent tests.

The next experiments were directed toward a separation of strontium and calcium nitrates. Definite amounts of a solution of strontium nitrate were measured from burettes into counterpoised beakers and weighed, as already described, the calcium nitrate was then added in solution, and the weight taken again. The water was evaporated and the dry salts dissolved again in the least possible amount of water, and boiled with amyl alcohol, (30 cm.^{3}) as before. The strontium salt was filtered off into a perforated platinum crucible containing an asbestos felt, dried and weighed as previously described. The calcium was determined in the form of the sulphate, by evaporation of the alcohol, treatment with an excess of sulphuric acid, and ignition.

Correction was made for the solubility of the strontium nitrate, and its consequent presence with the calcium, by calculating the amount dissolved in the portion of amyl alcohol employed to the condition of sulphate and subtracting that quantity from the apparent amount of calcium sulphate found. The results of this mode of proceeding are recorded in experiments (10) and (11).

	SrO taken.	SrO found. (corrected.)	Error.	CaO taken.	CaO found. (corrected.)	Error.
(10.)	0·0911 grm.	0·0932 grm.	0·0021 grm. +	0·0932 grm.	0·0907 grm.	0·0025 grm. —
(11.)	0·0915 grm.	0·0945 grm.	0·0030 grm. +	0·0933 grm.	0·0899 grm.	0·0034 grm. —

After making the correction in the manner specified it is evident that the amount of strontium indicated is greater than that originally taken. It is apparent, therefore, that the strontium nitrate must have been contaminated, probably mechanically, by the calcium salt, as the calcium salt is found to be correspondingly deficient in amount. It was thought best, therefore, to have recourse to a double treatment with the alcohol. Accordingly after the first boiling already described the alcohol carrying the greater part of the calcium in solution was decanted upon an asbestos felt under the conditions previously described and collected in a beaker placed to receive

it. The residue was then dried at a gentle heat over a radiator to remove amyl alcohol, dissolved in a few drops of water, treated with a drop of nitric acid to assure the condition of nitrate, and evaporated to dryness. After dissolving in a few drops of water 30 cm.^{3} of the alcohol were added, and the boiling repeated. The residue was filtered off upon the same felt through which the first portion had been decanted, and washed with amyl alcohol, care being taken to remove all particles of the residue from the beaker by careful rubbing. The crucible and residue were heated in an air bath at 150° C. as before, and then weighed. The filtrate from the two treatments and the washings were treated differently in two series of experiments. In Series II, the filtrate was precipitated with sulphuric acid, ethyl alcohol being added to secure thorough mixture. The precipitated sulphate was filtered off upon asbestos, heated to low redness and weighed. In Series III, the alcoholic filtrate was evaporated to a small volume, transferred to a weighed platinum crucible and evaporated. The residue was ignited to burn off organic matter, treated with sulphuric acid and again ignited at low redness and weighed.

SERIES II.

	SrO taken.	SrO found. (corrected.)	Error.		CaO taken.	CaO found. (corrected.	Error.	
(12)	0·1235 grm.	0·1239 grm.	·0004 grm.	+	0 1290 grm.	0·1271 grm.	0·0019 grm.	—
(13)	0·1237 "	0·1228 "	·0009 "	—	0·1246 "	0·1226 "	0·0020 "	—
(14)	0·1239 "	0·1239 "	·0000 "		0·1248 "	0·1223 "	0·0025 "	—
(15)	0·1974 "	0·1972 "	·0002 "	—	0·0502 "	0·0492 "	0·0010 "	—
(16)	0·1979 "	0·1978 "	·0001 "	—	0 0496 "	0·0482 "	0·0014 "	—

SERIES III.

(17)	0·0148 "	0·0155 "	0·0007 "	+	0·0256 "	0·0254 "	·0002 "	—
(18)	0·0183 "	0·0183 "	0·0000 "		0 !030 "	0·1015 "	·0015 "	—
(19)	0·0364 "	0 0366 "	0·0002 "	+	0 0516 "	0·0511 "	·0005 "	—
(20)	0·0365 "	0·0365 "	0·0000 "		0·0515 "	0·0513 "	·0002 "	—
(21)	0·0493 "	0·0494 "	0 0001 "	+	0 0515 "	0·0502 "	·0013 "	—
(22)	0·0497 "	0·0497 "	0·0000 "		0·0519 "	0·0511 "	·0008 "	—
(23)	0·0497 "	0·0503 "	0·0006 "	+	0·0249 "	0·0245 "	·0004 "	—
(24)	0·0729 "	0·0732 "	0·0003 "	+	0 0257 "	0·0251 "	·0006 "	—
(25)	0·0730 "	0·0732 "	0·0002 "	+	0·0255 "	0·0255 "	·0000 "	
(26)	0·0744 "	0·0744 "	0 0000 "		0·0258 "	0·0260 "	·0002 "	+
(27)	0·0912 "	0·0910 "	0·0002 "	—	0·1286 "	0·1276 "	·0010 "	—

The average error in the determination of strontium in both series is less than 0·0001 grm. + on the oxide; that of the calcium amounts to 0·0017 grm. — on the oxide in Series II, and to 0·0005 grm. — in Series III.

In both processes the correction for the solubility of strontium nitrate in amyl alcohol, determined as previously described, was applied—0·0020 grm. being added to the weight of the strontium oxide found after the double treatment with amyl alcohol, and 0·0035 grm. being deducted from the apparent weight of the calcium sulphate found before calculating it

to the form of the oxide. The latter of the two processes, which are identical so far as handling of the strontium is concerned, yields the better results in the determination of the calcium, doubtless because a trifling amount of calcium sulphate remains in solution in the final filtrate in the former process, while in the latter every trace should be recovered. The deposition of minute traces of calcium in the precipitation of the strontium nitrate, to which reference has been previously made, is evidently a matter of no significance in comparison with the ordinary errors of manipulation.

ART. VII.—*The Relation of Melting Point to Pressure in Case of Igneous rock fusion;* by C. BARUS.

To determine this important constant for diabase, I made use of the thermodynamic principle (Clausius, I, chap. vii, § 2). From my last note* the fusion specific volumes, solid and liquid, are known. Hence it is merely necessary to determine the latent heat of fusion.

Two series of measurements of the thermal capacity of diabase, containing 27 independent measurements, were made between 700° and 1400°. The first series gave me, in gram calories, for the mean specific heat, solid, between 800° and 1100°, ·304; for the mean specific heat, liquid, between 1200° and 1400° ·350; for the latent heat of fusion (1200°), 24; and for the heat set free on solidification (1100°), 16. Similarly the second series gave me, ·290, ·360, 24, and 16, respectively. The last series is much the more trustworthy and its accuracy may be inferred from the following pairs of values of temperature and thermal capacity: (solid) 781°, 180; 873°, 202; 948°, 227; 993°, 238; 1096°, 268; 1171° (incipient fusion?), 302; (liquid) 1166°, 310; 1194°, 318; 1197°, 319; 1215°, 327; 1218° 330; 1248°, 339; 1251°, 340 and 342; etc. Now whereas in my last note (l. c.), solidification did not set in above 1100°, evidences of fusion do not here show themselves until 1170° is reached. Rock fusion is therefore accompanied by hysteresis,† the lag being apparantly as much as 70°. It is this property which makes it possible to obtain sharp values of latent heat, for the rock can be operated on, either solid or liquid, at nearly the same temperature. In view of the great difficulty of obtaining the value of the melting point, however, I shall in the following state the conditions for 1100°

* This Journal, December, 1891.
† This Journal, xlii, p. 140, 1891.

and 1200° respectively, the latter being very near the melting point.

Combining the present series I with the former series III, I obtain for the relation of melting point and pressure, dT/dp, at 1200°, since $T=1470°$, $\sigma-\tau=\cdot0394/2\cdot72$, $r'=24$, $dT/dp=\cdot021$; and at 1100°, since $T=1370°$, $\sigma-\tau=\cdot0385/2\cdot72$, $r'=16$, $dT/dp=\cdot029$. Similarly combining the present series II with the former series IV, at 1200°, since $\sigma-\tau=\cdot0352/2\cdot72$, $r'=24$, $dT/dp=\cdot019$; and at 1100°, since $\sigma-\tau=\cdot0341/2\cdot72$ and $r'=16$, $dT/dp=\cdot026$.

Hence the probable *silicate* value of $dT/dp=\cdot025$ at 1170°, falls nicely within the margin (·020 to ·036) of corresponding data for organic substances (wax, spermaceti, paraffin, naphthalin, thymol). I may therefore infer that the relation of melting point to pressure in case of the normal type of fusion, is nearly constant, irrespective of the substance operated on, and in spite of enormous differences of thermal expansibility and (probably) of compressibility. A portion, in a given substance changed only as to temperature and pressure, the relation of melting point and pressure is linear.

The immediate bearing of all of this on Mr. Clarence King's geological hypothesis is now ripe for enunciation.

ART. VIII.—*The discovery of Clymenia in the Fauna of the Intumescens-zone (Naples beds) of Western New York, and its Geological Significance;* by JOHN M. CLARKE.

THE ammonoid genus *Clymenia* Münster, has not heretofore been found in North America. As early, however, as 1843, Professor Hall doubtfully referred* to this genus, a fossil from the Portage shales, the *Clymenia? complanata*, and in 1862† re-described the species without the mark of doubt, at the same time adding a new specific name, *C. Erato*, for a fossil from the same fauna. Subsequently these fossils were proved to be of the same species, and though the name *Clymenia* was still retained as late as 1876,‡ it was finally and quite properly abandoned in 1879.§

The present discovery of a true *Clymenia* in a lower Upper Devonian fauna containing *Goniatites intumescens* and various other primordial goniatites, was unexpected and is of considerable geological importance.

* Geology of New York, Report of the Fourth District, p. 244.
† Fifteenth Ann. Rept. N. Y. State Cab. Nat. Hist., pp. 63, 64.
‡ Illustrations of Devonian Fossils, expl pl. 70, figs. 6–11.
§ Palæontology of New York, vol. v, pt. 2, p. 455.

The material obtained is from a calcareous concretion found in Shurtleff's Gully in Livingston County, N. Y., not far up in the shales of the Naples beds. This concretion has also afforded specimens of an undescribed *Gephyroceras* of very common occurrence in this fauna, *Tornoceras uniangulare* Conrad, *Bactrites* sp. nov., or very like *B. carinatus* Münster, *Loxonema Noe* Clarke, *Palæotrochus præcursor* Clarke, *Platystoma minutissimum* Clarke, *Bellerophon*, sp. indes., *Styliolina fissurella* Hall, *Cardiola* [?] *Doris* Hall, *Lunulicardium*, sp. nov., common throughout the fauna.

The specimens consist of about thirty examples of a single species in an exceptionally fine condition of preservation, affording the various stages of growth from the protoconch to maturity. As the exterior of the shell is so exquisitely retained and the earlier whorls are compactly filled with silica it has been a difficult task to determine with precision the variations in the form of the suture.

Description of the species.—The mature individuals are of small size, the largest example retaining the chamber of habitation having a diameter of 14^{mm}. The outer chamber is long, extending nearly three-fourths the length of the last volution. The shell is widely umbilicate, the successive whorls scarcely overlapping; the number of revolutions from the proximal end of the protoconch is $5\frac{1}{2}$ or 6. The chamber of habitation is subtrapezoidal in section, widening at the base where its sides are rather abruptly incurved to embrace the ventral surface of the inner whorl. The sides slope outward with some convexity and the ventrum is flattened, sometimes very slightly convex or concave.

The *protoconch* is broad, transversely ellipsoidal, and has a diameter of 9^{mm}. In adolescent growth stages it is not prominent on account of the absence of any contraction of the tube at the beginning of the first chamber. In the Goniatitinæ this contraction is an important character especially well-developed in the genera of the *Primordiales*. The early whorls are broad and very shallow in section, and in them the flattened ventrum of the body whorl is not apparent. For the first four revolutions of the tube, the union of the successive whorls is essentially an apposition, the slight overlapping at maturity indicating a tendency to diminution of umbilication as a geratologous character. The 2d, 3d, 4th and 5th whorls are very broad on the periphery, their vertical to ventral diameter being as 1 to 3·2, 1 to 3, 1 to 2·5, 1 to 2, respectively. In the 4th whorl the ventral surface becomes rapidly convex by the filling out of the ventro-lateral slopes, and with the 5th and 6th whorls the increasing lateral appression brings into prominence the narrow flattening of the ven-

trum characterizing maturity. The body-chamber is covered with fine, elevated, falciform striæ which make a broad retral curve in crossing the latera, are bent forward sharply along a low depression just within the ventrum; along the low external carinæ they are again bent backward forming a series of filose festoons on the ventrum itself. On the early whorls these lines are not apparent; there the ornamentation consists of a series of lamellar spinous processes occurring at regularly increasing intervals. These originate on the median and outer portions of each whorl and are projected against the inner edge of the succeeding whorl. They present a concave face anteriorly and are, when entire, considerably extended at right angles to the axis of the shell. These varices appear on the first half of the third volution and from this point on, in a selected example, nine may be counted for the next volution; the whole number exhibited by the specimen to the last contact with the body whorl being seventeen. On the exposed whorl no further trace of the processes is observable than a tendency on the earlier half of the volution to the formation of pilæ or a bunching of the striæ.

The sipho.—The dorsal or internal position of the sipho has been observed in several instances. The siphonal funnel is long, conspicuously developed, and open along its inner surface. It does not appear to have extended across the air-chamber, as in the *Nothoclymeniæ* and I have seen no evidence of a true siphonal tube connecting these funnels.*

The sutures.—At maturity the septum is concave medially, convex at the sides. There is no ventral saddle; the ventral lobe is broad, about equal in width to, but less acute than the ventro-lateral saddle; the lateral lobe is narrower and there is a small, but well developed dorso-lateral saddle. On the internal edge of the septum there is an acutely angled external lobe and an elongate, narrow saddle from which the suture is continued into the siphonal funnel. Of the immature suture but a single example has been observed; at the end of the second revolution the ventral lobe is comparatively narrow, the ventro-lateral saddle very broad, neither the lateral lobe nor dorso-lateral saddle is developed, the lateral saddle being continued directly into the external lobe of the internal margin. It is, thus, evident that the accessory lobe and saddle of maturity are developed at a later stage of growth from the broad lateral saddle.

* Hyatt compares this arrangement of the siphonal funnels in Gümbel's group of the *Euclymeniæ*, to which our species belongs, to the "imperfect siphons which occur not infrequently among the Nautiloids, the connective wall being destroyed by maceration." Proc. Boston Soc. Nat. Hist., vol. xxii, p. 313.

The ornamentation of our species (which may be termed *Clymenia* (*Cyrtoclymenia*) *Neapolitana*, from its occurrence in the Naples beds) restricts its comparison to three well known species, namely: *Clymenia spinosa* Münster, *C. binodosa* Münster, and *C. subarmata* Münster. The last may be left out of consideration on account of important differences in the mature suture. The other two species belong to the same group, *Cyrtoclymeniæ* Gümbel (genus *Cyrtoclymenia* Hyatt) and in *C. spinosa* the figures given by Münster* and the description and illustration by Gümbel† show a similar structure and arrangement of the spinous processes on the ventro-lateral slopes of the whorls. The intervals between these on the earlier whorls are covered by fine concentric lines bending slightly forward over the ventrum but they have not the falciform curve of the striæ in *C. Neapolitana*. Gümbel described a specimen of that species (figures 2*a*, *b*, on his plate xvi) in which, over a portion of the last volution, the spinous nodes are reduced to bundles of striæ, strongly defined over the inner margin of the whorl, but spreading and losing their identity over the ventrum. In *C. binodosa* the ornamentation is less like that of the American form but the flattened ventrum is better defined and the suture more like that of *C. Neapolitana* than is that of *C. spinosa*.

The geological interest attaching to this fossil is very great. The genus *Clymenia* has been, wherever found, a most important horizon-marker of the uppermost Devonian It appeared abruptly and quickly attained a prolific and exceedingly variant development. Hyatt observes that "the whole range of transformations of the Goniatitinæ are paralleled in this short series (Clymeninæ) whose principal differential characteristic lies in the dorsal position of the siphon."‡

Kayser has shown that the *Clymenia* fauna occurring on the summit of the Enkeberg in Westphalia, is of later date than the Cypridinen-schiefer of Nehden (horizon of *Goniatites curvispina* and *Verneuili*) and is therefore the topmost member of the deep-sea upper Devonian series of the continent of Europe. Wherever found it has maintained this time-value. Richter, Gümbel and Kayser have demonstrated its position in its richest development in the Fichtelgebirge (Schübelhammer, Gattendorf, etc.). Tietze has described it in Silesia (Grafschaft Glatz), Siemiradski in Poland, Frech in Cabrières (Languedoc), Stur, Stache, Hoernes and Frech have established the horizon in Graz (Styria), and Karpinsky and Tschernyschew have identified it in the Urals. In Cornwall (South Petherwin) species

* Beitrag zur Petrefactenk. v, pl. 11, fig. 15.

† Ueber Clymenien in den Uebergangsgebilden des Fichtelgebirges, p. 48, pl. 16, figs. 1, 2.

‡ Proc. Boston Soc. *loc. cit.*

were long ago described by Phillips and McCoy and more recently the position of the *Clymenia* beds in South Devon (Lower Dunscombe) has been located by Ussher, Kayser, Tschernyschew and Frech. In his "Lehrbuch der geologischen Formationskunde," recently published (1891, p. 109), Kayser states that the genus is limited to the uppermost Devonian. Its presence therefore, in the Naples beds, at a horizon probably not more than 200–250 feet above the top of the Genesee shales, in association with a distinctly developed Intumescens-fauna, is an unique phenomenon.

The composition of this fauna in its first appearance in the *Styliola limestone* of the Genesee shales and its reappearance in the Cashaqua-Gardeau division of the Portage group has been recently discussed by the writer in brief.* In the concluding portion of my paper in the American Geologist attention was called to the abundance in the fauna of certain species of coniferous woods, and to the observations made upon them by their describers, Dr. Sir William Dawson and Professor D. P. Penhallow. The most abundant of these species is the *Dadoxylon* (*Cordaioxylon*) *Clarkii* Dawson, which Sir William has recently stated to be most near it its structure to *Araucarites Ungeri* Gœppert, from the Cypridinen-schiefer of Thuringia. *Cladoxylon mirabile* Unger, from the same flora, was identified some years ago by Dawson in the Styliola layer. Of accessory importance is the occurrence of *Kalymma grandis* Unger, (the original also from the Cypridinen-schiefer of Saalfeld) from the Black (Genesee) Shale at Moreland, Kentucky,† in association with a primordial goniatite not unlike *G. intumescens*. Thus we have in our Intumescens-zone a very important representation of the flora of the Cypridinen-schiefer as developed in Thuringia, and though the characteristic fossil, *Entomis serrato-striata*, is not known to occur here, yet there is an undescribed *Entomis*, abundant in places in the Styliola layer, which is not greatly unlike that species. It does not yet appear that the New York Intumescens-fauna furnishes any forms especially characterizing the cephalopod facies of the Cypridinen-schiefer (the Nehdener-schiefer or horizon of *Goniatites curvispina* = middle Upper Devonian of the Continent). Some collateral evidence of the Clymenia-kalk fauna, but not of the most satisfactory kind, is furnished by the abundance of species of *Tornoceras*, *Cardiola retrostriata*, an undescribed *Bactrites*, which may be compared with *B. carinatus*, Münster, *Loxonema Noe*, not unlike *L. arcuatum* Münster; there is also a species of finely striated

* Neues Jahrbuch fur Min., vol. i, p. 161, 1891; American Geologist, Aug., 1891. p. 86.

† Discovered by Dr. C. E. Beecher.

Lunulicardium not dissimilar from an unidentified form of this genus known to me from the Enkeberg. These are, however, molluscan types, occurring with, but not especially characteristic of the *Clymenia* fauna. Closer comparisons must await the fuller elucidation of our Intumescens-fauna, as a large number of its known species are yet undescribed.

It may be provisionally suggested that the fauna of the Naples beds embraces representatives of the whole series of the European Upper Devonian faunas from the base of the Goniatite limestone to the base of the Culm; that it is, therefore, a condensed time-equivalent of a series highly differentiated in the transatlantic Upper Devonian succession. There the indicial brachiopods, *Spirifer disjunctus*, *Orthis striatula*, *Rhynchonella acuminata*, range through the entire series; here the Intumescens-fauna at least, is almost entirely without representatives of these species, their allies or associates.* On the other hand, in rare instances, the members of the cephalopod or deep-sea facies of the lower Upper Devonian fauna are found in the succeeding brachiopod fauna; for example, *Goniatites intumescens*, *G. sinuosus* (=*G. intumescens*), *G. simulator* (=? *G. intumescens*) and *G. Chemungensis*.

Tschernyschew has found† these index brachiopods of the Upper Devonian in the *Clymenia* beds of the Urals (Horizont von Mursakaeva), and Hébert at an earlier date reported *Clymenia* with *Spirifer disjunctus* and *Orthis striatula* in the Ardennes near Etrœungt.‡

EXPLANATION OF FIGURES.

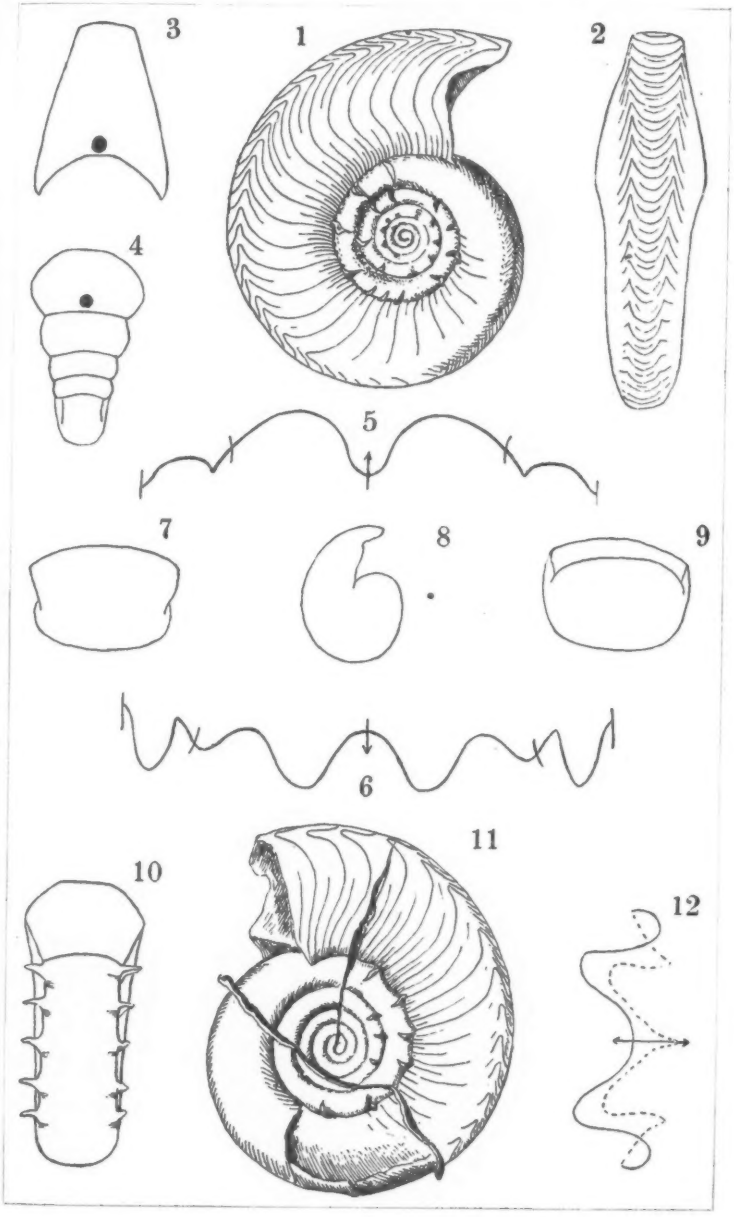
Clymenia Neapolitana, sp. nov.

Fig. 1. A nearly complete shell, slightly broken at the aperture. ×4.
Fig. 2. Profile of the same; showing the broad ventrum and recurved striæ.
Fig. 3. Transverse section near the beginning of the 5th whorl. ×6.
Fig. 4. Transverse section at the end of the 1st, 2d, 3d and 4th whorls. ×6.
Fig. 5. The form of the suture at 2¼ revolutions.
Fig. 6. The mature suture.
Figs. 7, 8 9. Three views of the protoconch. ×10.
Fig. 10. Ventral view of an immature shell; showing the character of the spinous projections; these are somewhat restored on the left of the figure. ×6.
Fig. 11. A mature shell, showing a nodation of the ventral margin of the body-chamber. ×4. The specimen is crossed by projecting seams of quartz.
Fig. 12. The mature suture viewed from above, the dorsal course being in a dotted line. These figures of the suture are not drawn to scale.

* The only member of this fauna suggesting the brachiopod facies of the lower Upper Devonian of Europe is a small *Strophalosia* or *Productella* recalling the species usually identified by European writers with the *Productus subaculeatus* Murchison.

† Fauna des mittleren und oberen Devon am West-Abhange des Urals, 1887.

‡ Bull. de la Soc. géol. de France. 2e ser. tom. 12, p. 1178, 1855.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ART. IX.—*A new Meteoric Iron from Garrett Co., Maryland;* by A. E. FOOTE. With Plate I.*

A PHYSICIAN residing near the Maryland line of Pennsylvania recently brought to me an iron mass to learn if it was meteoric, and this it has proved to be. It was discovered in Garrett Co., Md., about twelve miles from the Post Office of Lonaconing, not far from the boundary. It was ploughed up about three or four years ago by a boy in a field. According to an analysis by Dr. Koenig, it contains over 11 per cent of nickel and cobalt, the proportion of cobalt being unusually high.

It is one of the best octahedral etching irons known, being even more characteristic than the most of those that have been used for printing directly on paper. Besides the striking reticulated octahedral structure, it shows a large number of secondary lines regularly disposed with reference to the principal markings. These I believe to be similar to those described by Prof. J. Lawrence Smith, in a Wisconsin meteorite,† under the name of Laphamite markings. The original weight was 45 oz. but it has been reduced by analysis, cutting, polishing etc. to 36½ oz. The locality is especially interesting since this is one of the very few discovered in the Middle or Eastern States.

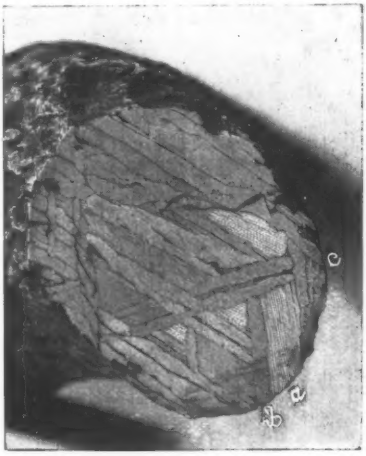
The following is Prof. J. Lawrence Smith's description of the Laphamite markings on the Wisconsin iron, and it applies to the Garrett County siderite, except that the bright figures are the ones that show the secondary marking.

"The Widmanstättian figures are, *a*, bright metallic, with convex ends and sides; *bc*, of a darker color, are the other markings, usually smaller, and with the sides and ends concave. The material of which these dark figures are composed seems to have enveloped the lighter colored portion, which serves to make the dark lines so beautifully conspicuous. A good pocket-glass will show that the dark figures are striated, with lines at right-angles to the bounding surfaces. When the figure is nearly square the lines extend from each of the four sides, but when much elongated, as at *c*, they are parallel with the longer sides. Often these lines do not reach the middle of the figure, where only a confused crystallization can be detected. In the interior of the elongated figures the lines are quite irregular, often running together and showing a striking resemblance to woody fiber. The nature of these markings may be easily understood. They indicate the axes of minute columnar crystals, which tend to assume a position at right-angles to the surface on cooling."

* A verbal notice of the discovery was made to the Academy of Natural Sciences of Philadelphia, in November.

† This Journal, xlvii, 271, 1869.

1.



2.

Meteoric Iron from Garrett Co., Md. Fig. 1, Etched surface. Fig. 2, Entire mass. Original weight, 45 oz. Present weight, 36½ oz.

ART. X.—*Farmington, Washington Co., Kansas Aerolite;* by GEORGE FREDERICK KUNZ and ERNEST WEINSCHENK, PH.D.

ON Wednesday, June 25, 1890, at 12.55 central time, a roaring, rumbling sound was heard within a radius of one hundred miles around Washington, Washington County, Kansas, and many observers noted a meteorite traveling from south to north, which in its course left a double trail of smoke. The sun at the time was shining brightly, and hence no light was seen. The explosion was likened by various observers to a bolt of lightning, the bursting of the boiler of an engine, or the report of a distant cannon. The largest portion of the meteorite, weighing 180 pounds, fell on the farm of Mr. W. H. January, who was greatly alarmed, as it struck very near him while he was under his wagon repairing it. This piece penetrated the hard shaly earth to a depth of four feet. Forty pounds of it were broken off and distributed before it was placed on exhibition after which it was sold and resold several times, and now belongs to Prof. Henry A. Ward of Rochester. Its dimensions now are $16\frac{1}{2} \times 16\frac{1}{2} \times 8$ inches; weight 136 pounds. A distinct mass weighing nine pounds, now in the possession of George F. Kunz, was found on the farm of John Windhurst; and it is evidently this piece which made the second trail of smoke.

The sound was noticed throughout a number of counties, both in Kansas and Nebraska, as a thunderous roar, which at Clifton, twenty-five miles from the point of fall, was heard above the noise of a passing railroad train. The meteorite was seen over a much wider area even than its sound covered. Reports of observers are given from many places, ranging from Beatrice, Nebraska, 40 miles northeast of the point of fall, to Cedar Junction, Kansas, 130 miles southeast, and Halstead, Kansas, an equal distance south by west. To those north of the point of fall, it appeared as a brilliant object moving southward, while to observers south of that point, its motion seemed northward. As Prof. F. H. Snow, who gives a full account of the circumstances attending the fall, remarks,* these facts indicate that its descent must have been not far from vertical, as is also shown by the nearly perpendicular hole, about four feet deep, which it made in the earth.

The actual fall was witnessed by Mr. January, as he came out from under his wagon alarmed by the extraordinary noise,

*Science, July 18, 1890.

and also by Miss Guild, a teacher in the Washington County Normal Institute, who was driving on the neighboring road, a hundred yards distant. Both came to the spot in a very few minutes; and Mr. January began promptly to dig for the object, and with the aid of neighbors reached its upper surface in an hour. But so firmly had it embedded itself in the shaly clay, that it was three hours before it was removed. When reached it was not hot. It had cracked into two portions, the the smaller of which was the forty-pound mass broken up and carried away by the people of the neighborhood.

At the moment of its fall, the earth was thrown upward and outward for a distance of eight to ten yards or more.

The following analysis was made by Mr. L. G. Eakins through the courtesy of Prof. F. W. Clarke, chief chemist of the U. S. National Museum, Washington, D. C.

Approximate composition of the mass.		Analysis of the iron.	
Nickeliferous iron	7·7	Fe	86·76
Troilite	5·0	Ni	12·18
Siliceous part soluble in HCl	46·0	Co	·83
" " insoluble " "	41·5		
	100·2		99·77

Analysis of the siliceous part from which all magnetic material had been extracted.

	Soluble in HCl. [1]	[2]		Insoluble in HCl. [3]	[4]
SiO_2	19·15	38·50	SiO_2	24·29	53·80
FeO	16·15	23·54	Cr_2O_3	·64	1·41
NiO	·34	·69	Al_2O_3	1·95	4·32
CoO	tr.	tr.	FeO	5·41	11·98
MnO	·17	·34	MnO	tr.	tr.
CaO	·06	·12	CaO	1·84	4·08
MgO	18·31	36·81	MgO	10·10	22·37
S	1·97	----	K_2O	·12	·27
			Na_2O	·80	1·77
	56·15	100·00		45·15	100·00

Analysis No. 1 is the direct analysis of the portion soluble in HCl. Analysis No. 2 is calculated to equal 100. Analysis No. 3 the composition of the insoluble part. Analysis No. 4 calculated to equal 100.

The nickel-iron of this specimen shows, as is generally the case in stony meteorites, a higher percentage of nickel and cobalt than is usual in meteoric irons. The constituent in this stone which was dissolved by hydrochloric acid, is shown by that fact to be olivine, in which the proportions of magnesia

and iron are as three to one. The crust on this meteoric stone is black and dull, frequently over 1 mm. in thickness. Macroscopically the Washington meteorite resembles a doleritic lava, of dark gray color and splintery fracture, with white radiated chondri which protrude from the ground-mass. The specimens also contain druses lined with crystals of sulphide of iron, the faces of which are rounded and present the appearance of having flowed through fusion, thereby rendering it impossible to measure the angles. No analysis of this material was made, although from the total lack of oxidation it might have promised good results.

Nickeliferous iron, which in the fracture, is only slightly visible, becomes conspicuous on a polished surface, showing that it is present in many grains, some exceedingly minute, others up to 4 mm. in diameter. In one instance a vein 10 mm. long and 1 mm. wide penetrated the mass, and on the surface of a polished section appeared bright serpent-like veins. The crust of the meteorite is black, hard and uneven, and the surfaces 0·8 mm. large are dull and often of beadlike form. Under the microscope, the porphyritic character of this meteorite is readily recognized; radiated and broken chondri and crystals of various minerals make up the microfelsitic groundmass.

All these are entirely enveloped in an opaque, evidently glassy magma, the dark shade of which gives the color to the whole. This dissolves in cold HCl, imparting a yellow tint to the acid. Heating to redness does not destroy the color, which fact surely precludes the idea of its being due to the presence of any organic matter. Prominent are crystals and fractured masses of olivine, which feature is of rather rare occurrence. This olivine is rich in orientated opaque inclusions, and has also a distinct cleavage, which is seldom observed in olivine. The optical character was perhaps disturbed through the rapidity of its crystallization.

Distorted undulation is common. Rhombic pyroxene is readily identified, frequently with a fibrous cleavage and monosymmetric augite; also the monticellite-like silicate described by Tschermak. The Washington county meteorite belongs to the black chondrites and has the greatest resemblance to the meteorite of Sevenkof. It is undoubtedly not a polygenius conglomerate but was rapidly formed out of the fluid glassy magma.

The thanks of the describers are due to Prof. F. W. Clarke and Mr. L. G. Eakins of the U. S. Geological Survey for the analysis, to Prof. Henry A. Ward for facts concerning his mass, and to Mr. Daniel Scheckler of Washington, Kansas, for obtaining one mass and information attending the fall.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On Isomorphism.*—In an elaborate paper, Retgers has given the results of his later investigations upon isomorphism. In an earlier paper he had pointed out the indefinite capability of admixture of two crystalline isomorphous substances, and shown that the best experimental proof of isomorphism was the continuous variation in the physical properties of these mixed crystals. The physical property selected for the present research was color. The substances made use of were potassium perchlorate $KClO_4$ which is colorless, and potassium permanganate $KMnO_4$ which is dark purple-red; or potassium sulphate K_2SO_4 and potassium manganate K_2MnO_4, the latter being green. The two salts to be examined was dissolved in water and a drop of each of the warm solutions were placed on a microscopic slide; these drops being allowed to touch or being connected with each other by a narrow channel of liquid so that slow diffusion might go on between them. If the salts are really isomorphous, like those above mentioned, crystals are obtained having all depths of color. Moreover a crystal may have its ends of different depths of color, with all intermediate shades between. But if the salts experimented on are not isomorphous, no such gradation of color is observed in the crystals. Adopting the axiom that if a substance B is isomorphous with a substance A and also with a substance C, the substances A and C are isomorphous with each other, the author finds the perchlorates of ammonium, potassium, rubidium and cæsium to be isomorphous with potassium permanganate and with each other. $LiClO_4.(H_2O)_3$ and $LiMnO_4.(H_2O)_3$ form mixed crystals. $AgClO_4$ crystals were colored by an unstable rhombic modification of $AgMnO_4$; the mixed crystals being highly pleochroic, changing from blue-green to ruby-red on rotating the nicol prism. Mixed crystals containing manganate retain their blue-green color for weeks. K_2SO_4, $(NH_4)_2SO_4$, Rb_2SO_4, Cs_2SO_4, Tl_2SO_4, K_2SeO_4, Rb_2SeO_4, Cs_2SeO_4, Tl_2SeO_4, K_2CrO_4, Rb_2CrO_4, Cs_2CrO_4, K_2MnO_4, Rb_2MnO_4 and Cs_2MnO_4 are all isomorphous forming rhombic (pseudo hexagonal) prisms and pyramids. $(NH_4)_2SeO_4$ crystallizes in monoclinic plates. $(NH_4)_2CrO_4$ and Tl_2CrO_4 are only slightly soluble; the former being probably isodimorphous with K_2CrO_4. The sulphates and selenates of sodium and silver are isomorphous, crystallizing in rhombic pyramids strongly double-refracting. The chromates of sodium and silver and the manganate of sodium are isomorphous, probably; as are the sulphate, chromate and selenate of lithium, when anhydrous. $KLiSO_4$ and $KLiSeO_4$ are not isomorphous but morphotropic. K_2WO_4 and K_2MnO_4 are isomorphous with K_2MnO_4. The author points out that between sulphates and sele-

nates there is mostly direct isomorphism; between sulphates and chromates, isodimorphism is common; while between sulphates and molybdates or tungstates it is the rule.—*Zeitschr. physikal. Chem.*, viii, 6, July, 1891; *J. Chem. Soc.*, lx, 1151, October, 1891. G. F. B.

2. *On Crystallized Persulphates.*—In 1878, Berthelot obtained persulphuric oxide S_2O_7 by subjecting a well cooled mixture of sulphurous oxide and oxygen to the silent electric discharge, and persulphuric acid by electrolyzing strong sulphuric acid.* Marshall, in the course of an investigation on the oxidation of double cobalt salts by electrolysis, observed the production of colorless crystals in the electrolytic cell, which at first were supposed to be potassium sulphate; but which gave only a slight precipitate with barium chloride, until the solution was heated and were therefore persulphate. To prepare the persulphate in larger quantity, a saturated solution of hydrogen potassium sulphate was electrolyzed, the kathode being contained in sulphuric acid placed in a porous cell. On passing a current of 3 to 3½ amperes for two days, a white crystalline deposit began to form, which was separated from the solution, drained and dried on porous plates; the process being repeated with the mother-liquor until sufficient material was collected. By solution in hot distilled water and cooling, the salt is deposited in minute prisms, the decomposition being inconsiderable. By slow cooling large tabular crystals are formed, apparently asymmetric. On analysis, the formula KSO_4 was obtained, the size of the molecule being determined from the conductivity of the solution. Potassium persulphate is sparingly soluble in cold water, 100 parts of water at 0° dissolving 1·75 parts of KSO_4. Its solution gradually decomposes at ordinary temperatures with evolution of oxygen, though slowly; a pure solution even after three months containing the greater part of the persulphate undecomposed. By similarly electrolyzing hydrogen ammonium sulphate, ammonium persulphate was obtained, in the form of long thin prisms, apparently rhombic, which on spontaneous evaporation, may become large, transparent lozenge-shaped monosymmetric tables. It is very soluble in water, 100 parts at 0° dissolving 58·2 parts of the salt. In consequence of this solubility, this salt was used in the preparation of the other persulphates. By treating a saturated solution of ammonium persulphate with barium hydrate, barium persulphate is produced, which after re-crystallizing at a low temperature, is obtained in beautiful prisms; or when the mother-liquor is concentrated in a vacuum, in large interlocking prisms having a monosymmetric appearance. This barium salt has the formula $Ba(SO_4)_2.(H_2O)_2$. It is very soluble in cold water, 100 parts dissolving 39·1 parts of the anhydrous or 52·2 parts of the crystallized salt. Lead persulphate was obtained as a solid crystalline mass, very deliquescent and having the probable for-

* This Journal, III, xv. 209, March, 1878.

mula $Pb(SO_4)_2 . (H_2O)_4$. Zinc and copper persulphates were also produced as deliquescent crystalline needles. All attempts to prepare sodium, lithium and magnesium persulphates were unsuccessful owing apparently to their exceeding solubility.—*J. Chem. Soc.*, lix, 771, October, 1891. G. F. B.

3. *On the Preservation of Sodium.*—According to ROSENFELD, when sodium which has been kept under mineral oil and is covered with a crust, is immersed in a mixture of petroleum three parts and amyl alcohol one part, or rubbed with a cloth soaked with this mixture, it acquires at once a silvery luster. If now it be put into petroleum containing 5 per cent amyl alcohol, then washed with pure petroleum and kept in petroleum containing one half to one per cent of amyl alcohol, it preserves this luster for a long time; becoming covered very slowly however with a film of sodium-amyl oxide which is easily removed with filter paper. Potassium and lithium can be purified similarly. Sodium thus cleaned combines at once with mercury, evolving light. By pressing clean sodium and potassium together under a mixture of one part amyl alcohol and nine parts petroleum, the liquid alloy of these metals is easily obtained. By mixing one gram of the clean sodium rubbed to a fine powder with three grams of salt, with 0·7 grams of sulphur, avoiding pressure, combination takes place with the evolution of light and sodium sulphide is formed. Selenium and tellurium behave similarly.—*Ber. Berl. Chem. Ges.*, xxiv, 1658; *J. Chem. Soc.*, lx, 982, Sept. 1891. G. F. B.

4. *On New Oxygen Compounds of Molydenum and of Tungsten.*—PÉCHARD has examined the yellow coloration produced by the action of hydrogen peroxide upon molybdates and tungstates, and concludes that it is due to higher oxygen compounds of these metals. When potassium trimolybdate is treated with hydrogen peroxide it dissolves forming an orange-yellow solution which deposits on concentration yellow crystals apparently triclinic, having the composition $K_2Mo_2O_8 . (H_2O)_4$. Heated gently in a vacuum, the crystals lose water and oxygen and leave a residue of acid potassium molybdate. The ammonium salt is similarly prepared. Both salts are decomposed by alkalies with evolution of oxygen. They evolve chlorine when treated with hydrochloric acid and set free iodine from potassium iodide. In the same way, sodium paratungstate boiled for a few minutes with hydrogen peroxide becomes yellow in color and is no longer precipitated by nitric acid. On evaporation the solution deposits white crystals having the composition $Na_2W_2O_8 . (H_2O)_2$. The above salts are regarded by the author as establishing the existence of per-molybdic and per-tungstic oxides Mo_2O_7 and W_2O_7, as well as the corresponding acids, $H_2Mo_2O_8$ and $H_2W_2O_8$.—*C. R.*, cxii, 720, 1060; *J. Chem. Soc.*, lx, 988, Sept. 1891. G. F. B.

II. Geology and Mineralogy.

1. *Bibliography undertaken by the International Congress of Geologists.*—Mr. G. K. Gilbert communicates to the Journal the following letter from Mr. Em. de Margerie, Secretary of the International Committee on the Bibliography of Geology. It sets forth the organization and plans of the Committee. Geologists residing in North America who have prepared or are preparing bibliographies of any portion of the literature of geology are requested to communicate with Mr. Gilbert. (Address: G. K. Gilbert, U. S. Geological Survey, Washington, D. C.).

International Congress of Geologists: Committee on the Bibliography of Geology. Paris, Rue de Grenelle 132, Nov. 20, 1891.

Sir: At the meeting of Tuesday, September 1, 1891, the International Congress of Geologists, assembled at Washington, on motion of Messrs. H. S. Williams and de Margerie, appointed a permanent international committee charged with the duty of centralizing the information relating to geologic bibliography. This committee, which is authorized to add to itself new members in unlimited number, comprises at present Messrs. Frech (Germany), Gilbert (North America), Golliez (Switzerland), Gregory (England), de Margerie (France), Reusch (Scandinavia), Steinmann (South America), Tschernyschew (Russia), Tietze (Austria-Hungary), and Van den Broeck (Belgium).

The end to be attained is threefold: (1) to prepare a list of the geologic bibliographies already in existence; (2) to prepare an inventory of those parts of geologic literature which have not as yet been the subject of such methodic abstracting, in order to prepare the way for undertaking comprehensively the retrospective bibliography of the science; and (3) to proceed to the periodic registration of its current bibliography.

The first meeting of the committee took place during the excursion to the Rocky Mountains. The following are the minutes:

"The International Committee on the Bibliography of Geology met September 20th, at 8 o'clock in the evening, in one of the cars of the special excursion train, between Manitou and Denver (Colorado). Present, Messrs. Frech, Gilbert, Golliez, de Margerie, Reusch, Steinmann, Tschernyschew, Tietze and Van den Broeck. Prof. H. S. Williams also was present at the meeting.

"Mr. Gilbert was by acclamation elected President of the Committee and Mr. de Margerie, Secretary. Mr. de Margerie will take charge of the correspondence for Europe, and undertakes to transmit to Mr. Gilbert all the documents intended for printing.

"In regard to retrospective bibliography, Mr. Golliez announced to the committee that the Geological Survey of Switzerland is preparing a geologic bibliography of Switzerland, which it will probably take several years to complete. Mr. Tschernyschew announced the existence of a catalogue of the same nature

on the north of Russia, as yet unpublished, of which he is the author. Finally, Mr. Van den Broeck called attention to the general bibliography of Belgium, which is to comprise a list of all documents relating to the geology of that country published in the course of the 19th century.

"After a short discussion, the committee decided to confine its efforts for the time being to the preparation of a list of the partial geologic bibliographies already in existence. Each member of the committee is to perform that part of the work which relates to the country he represents. For Spain, Italy and Portugal, which countries sent no representatives to Washington, the committee will address itself to the directors of the geological surveys of these three states. Mr. Tietze agrees to take charge of the bibliography of the Balkans, and Mr. de Margerie will try to fill out any gaps that may exist in the collection of documents gathered by the various members of the committee as regards Asia, Africa and Oceanica. The manuscripts must be sent to the Secretary before Easter, 1892, in order to be printed with the proceedings of the Washington meeting.

"The projected list will comprise the detailed titles of works entering into the following categories:

"(1) *Regional or local bibliographies.* (Examples: Geological Bibliography of Italy; Geological Bibliography of the counties of England, by Whitaker; Catalogue of the publications of the American surveys, by Prime).

"(2) *Systematic bibliographies*, that is to say, relating to a defined group of facts, (e. g. Bibliography of the various classes of rocks, inserted in Rosenbusch's Petrography; Bibliography of the Upper Jurassic, by Neumayr; glaciers, volcanoes, etc.)

"(3) *Personal bibliographies.* (Catalogues of the geologic publications of one author, like those that often accompany necrologic notices; Royal Society's catalogue of scientific papers, etc.)

"(4) *Catalogues of geologic maps*, (e. g. Mapoteca geologica Americana, by Marcou).

"(5) *Annual geologic bibliographies*, either general (e. g. Geological Record; Revue de geologie, by Delesse and de Lapparent; Annuaire geologique, by Dagineourt) or special (e. g. Revue geol. Suisse, by E. Favre and Schardt; Bibliotheque geologique de la Russie, by Nikitin; Record of American Geology, by Darton.)

"(6) *General tables of special periodicals or series*, (e. g. the Repertorium to the Neues Jahrbuch für Mineralogie; Index to the publications of the Geological Society of London, by Ormerod; Table of Paleontographica; List of geological maps published in the Quarterly Journal, by R. Bliss.)

"(7) *Printed catalogues of special libraries*, (e. g. Catalogue of the library of the Geological Society of London; Catalogue of geologic works found in the libraries of Belgium, by Dewalque.)

"As regards the scope to be given the work, the committee thinks proper for the present to exclude all documents of purely

mineralogic or paleontologic nature; on the other hand, information relating to petrography, physical geography, applied geology, mineral waters, and prehistoric archeology will be included. For the rest, full latitude is left in this respect to the collaborators, the editor being empowered to extend or abridge manuscripts with a view of securing proper uniformity in publication.

"Important manuscript bibliographies, the existence of which may be known to the members of the committee, are to be indicated in the proper places, stating name and address of author.

"The publication will be in French, but manuscripts may be prepared in the language of the country whence they come, to be translated afterward under the direction of the editor.

"Titles must always be given in the language of the original publication; they will not be followed by a French translation except in case they belong to a language other than English, German, Italian or Spanish. The indication of the author's name, place of publication (with the publisher's name in the case of a separate work), date, size and number of pages, shall be as exact and detailed as possible: furthermore it is desired to have stated the approximate number of entries contained in each bibliography, adding summary information regarding its nature, such as: "Alphabetic catalogue by authors' names; Catalogue classified by order of dates; Simple list of titles; Each article is followed by a resumé; The number of plates is not given, etc." The limiting dates of the publications catalogued in the bibliographies are also to be noted, (e. g. 1802 to 1888.)

"In case a bibliography bears no printed title, which often happens with such as are appended to special works or memoirs, it will be proper to define its subject by means of a phrase in brackets: [. . . .], giving after this the complete title of the document in which the bibliography is comprised.

"Publications which, without pretending to take the form of a methodic bibliography, contain the detailed history of the study of a question of general interest or of a country, are to be mentioned.

"In order to facilitate the final classification of subjects for the purpose of printing, the collaborators are requested to prepare their work on separate slips."

The Secretary, EMM. DE MARGERIE,

To Mr. G. K. Gilbert, Member of the Committee for North America.

2. *Experimental researches* (1) *On the deformations of a Sphere by contraction and pressure, and* (2) *On the part played by Vapors in different geological phenomena;* by Prof. A. DAUBRÉE.—Professor Daubrée has been continuing his very valuable researches in experimental geology by new experiments on the effects produced by pressure and by vapors in different geological phenomena. The effects of contraction, described in the Comptes Rendus, for May, 1890, are obtained by covering a distended ball of caoutchouc, arranged to have the form of a flattened sphe-

roid, with a coating of paraffin or beeswax, and then allowing it to slowly contract. Folds, fractures, and elevations are obtained having interesting relations to those which have been observed in the earth's structure and features. In other experiments, on subjecting a ball of caoutchouc to pressure, the effects of pressure normal to the surface were obtained.

The new experiments on the effect of vapors, are described in papers in the Comptes Rendus for 1890 and 1891 (the last in August, 1891), and also in part in a communication to the Geological Society of France of February, 1891. Two of the subjects illustrated are (1) the pressure of exploding materials, as guncotton, and (2) the production of more or less cylindrical perforations, tunnel-like, along fissures by vapors suddenly developed, a form of fracture called by Daubrée a diatreme. The origin of the conduits of volcanoes and explosive eruptions, and of the diamantiferous pipes of South Africa is thus explained by the author; and also the extrusion of the trachyte of trachytic domes, the lofty throws of volanic cinders and rocks and other related volcanic products, and the forms of the ejected broken blocks and lapilli. To these projected rocks or fragments, the name *ephyseme* is proposed, from the Greek for *something blown out.* The explosive agent recognized in the natural operations is, in general, the vapor of water suddenly generated. Other effects obtained are the erosion and fusion of granite, and other substances; the production of molecular transfer or flow, resembling that of plasticity, and a resoldering or remoulding of a crushed rock. The great heights of the more remarkable volcanic mountains are reviewed and their groupings. On the occurrence of similar heights in the mountains of a group and their origin through diatremes, Prof. Daubrée says: "it is as if each corresponded to a maximum of pressure proceeding from the same infra-granitic reservoir, or from similar reservoirs of whose pressure it gives a measure, like the tube of a manometer in the open air.

The paper published in the Bulletin of the Geological Society of France contains figures illustrating the methods of experiment and the various results, and reviews their general applications to volcanic and other geological phenomena. Prof. Daubrée observes that in contrast with the forms of fractures of the earth's crust which are linear, parallel, and are produced by horizontal pressure attending contraction, diatremes or "topic dislocations" are the effect of action concentrated on a single point, of vertical projection by a gaseous material acting with great velocity under heavy pressure "une sorte de coup de canon, dont l'âme serait une diatrème qui viserait le zénith." These memoirs of Prof. Daubrée will be read with great profit by geologists.

3. *A classification of Mountain Ranges according to their Structure, Origin and Age;* by WARREN UPHAM (Appalachia, vi, April, 1891).—Mr. Upham divides mountain elevations into (1) folded, (2) arched, (3) domed, (4) tilted, (5) erupted, and (6) eroded. The first division is exemplified in the Appalachian

structure; the second, in the Uinta Range; the third in those of laccolite origin, as the Henry Mts.; the fourth, in the Wasatch, it having been "elevated along fault-planes which form its western boundary," and in the Sierra Nevadas, its "fault lines bounding it on the east; the fifth, in volcanic cones and ridges; The sixth, in elevated plateaus sculptured into mountain shapes. Elevations of the first kind are attributed to force acting laterally, due to the earth's contraction, and those of the following four to force acting vertically upward. Mr. Upham remarks that greater pressure of some portions of the crust than of others upon the plastic interior would induce each phase of upward force in mountain-building. Where the relations of intense heat, immense pressure, and chemical influences, with presence of water or its farther ingress, have allowed portions of the interior, often of great extent, to become liquid lava, its extravasation by the same pressure has formed laccolite mountains and erupted mountain masses, while many volcanic cones have been mainly built up of fragments of solidified lava, much of it so fine as to be called ashes explosively ejected.

4. *On the Geology of Quebec City, Canada*; by HENRY M. AMI, M.A., F.G.S., of the Geological Survey of Canada.—From the Canadian Record of Science, April, 1891.—Much diversity of opinion has existed as to the exact geological position of some of the terranes at and about Quebec City, as also along the whole line of the great Appalachian or St. Lawrence-Champlain. With regard to the rocks forming the Citadel Hill or promontory of Quebec (Cape Diamond), an elaborate review of the opinions that have been presented is given in Dr. Ells's last report to Dr. Selwyn (1888), published by the Geological Survey of Canada, which includes the history from Dr. Bigsby's paper published in 1827, down to Prof. Lapworth's Report, etc., published in the Transactions of the Royal Society of Canada for 1887.

The Rocks of Quebec have been referred to the age of the Quebec Group (Levis Division); but the majority at present regard them as newer than the Trenton limestone, viz: of "Trenton-Utica," "Utica-Hudson," or "Lorraine" age. The fauna of the Norman's Kiln shales, that of the Marsouin, of the Tartigo River, Griffin Cove and Gagnon's Beach Rocks, as well as that from Crane Island, N. W., or False Point of the Island of Orleans, Quebec City, Etchemin River, between St. Henry and St. Anselme, Drummondville, and other localities in Maine, Vermont and New York States constitutes one large assemblage of forms peculiar to one terrane.

The fauna of the Lorraine shales, on the other hand, as it is characterized at Montmorency Falls, Côte Sauvageau, in the St. Charles Valley near Quebec, at Charlesbourg (near the Church), two miles above St. Nicholas, Yamaska River, Rivière des Hurons, and in the undisturbed regions in Ontario at Ottawa, Toronto, Weston, Oakville, Collingwood, etc., intermediate between

the Utica terrane and the base of the Silurian, marks another terrane.

These two faunas are very distinct both in their paleontological and stratigraphical relations. The Lorraine terrane, according to Dr. Selwyn's classification of formations ("Index to the Colours and Signs used by the Geological Survey of Canada,") has a definite position, viz: at the summit of the Cambro-Silurian or Ordovician system. The strata of Quebec, either on physical or paleontological grounds, cannot be referred to the Lorraine, nor to the Utica, the Trenton or the Black River formation.

Sir William Logan referred the Quebec City rocks to the Levis division of the Quebec group. From examinations recently made, the fauna which Mr. Weston, Mr. Giroux, l'Abbé Laflamme and the writer have been able to obtain from the rocks of that locality, presents some fifty species, including graptolites, brachiopods, ostracods and trilobites, different from Levis forms and yet capable of being correlated with forms from a portion of the Quebec group of Logan, as described in his Newfoundland section, as also with Cambro-Silurian strata in the Beccaguimic valley of New Brunswick.

The strata at Quebec City appear to me to occupy a position in the Ordovician system higher than the Levis formation, being akin to it, but lower than the Trenton, and are probably an upward extension of that peculiar series of sedimentary strata in the St. Lawrence valley, which, owing to the conditions of deposition Sir William Logan advisedly classed under the term "Quebec Group." This would make the rocks about equivalent to the Chazy formation of New York. As to the propriety of retaining the term "Hudson River" group, in geological nomenclature, there may be doubt. It would very naturally follow, however, that some such designation as the "Quebec terrane" or "Quebec formation" would be most acceptable for the Quebec City rocks, or those which constitute the citadel and main portion of Quebec City and other synchronous strata. The term "Hudson River" is extensively used throughout North American geological nomenclature to designate the series of strata above the Trenton limestone, much more so than the equivalent term, "Lorraine," defined and very carefully used by Emmons. While neither term is objectionable, and both have been used by various authors for the same horizon, it appears most practical now to retain the term Hudson River, or Hudson Terrane, which has been most extensively used and adopted in North American geology, as this would entail much less confusion, and would thus serve the ends of geological science more effectively.

The most characteristic species of graptolites peculiar to the Quebec terrane are the following:—*Cœnograptus gracilis* Hall, *Dicellograptus sextans* Hall, *D. divaricatus* Hall, *Dicranograptus ramosus* Hall, *Diplograptus foliaceus* Murchison, *D. Whitfieldi* Hall, *D. marcidus* Hall, *Climacograptus bicornis*

Hall, *C. bicornis*, var. *tricornis* Lapworth, *Corynoides calycularis* Nicholson.

In a paper which the writer is now preparing for the Royal Society of Canada, the various forms characterizing the Sillery, Levis and Quebec divisions of the Quebec Group in Canada as now understood, and constituting the natural series of sedimentary strata to which Sir William Logan had given that very appropriate term will be tabulated and the paleontological grounds for their separation made evident.

5. *Geological and Natural History Survey of Canada.* Annual Report (new series) vol. iv, 1888–89.—This large volume, recently issued, contains after the summary reports of the operations of the Geological Survey for the year 1889, by the Director, (65 pp.), the following papers:

On a portion of the West Kootanie District, British Columbia, by G. M. Dawson, (65 pp.) On an exploration in the Yukon and Mackensie Basins, by R. G. McConnell, (144 pp.) Exploration of the glacial Lake Agassiz in Manitoba, by Warren Upham, (121 pp.) On the mineral resources of the Province of Quebec, by R. W. Ells, (158 pp.) On the surface geology of Southern New Brunswick, by R. Chambers, (88 pp.) Chemical contributions to the geology of Canada, by G. Christian Hoffmann, (7 pp.) Mining and Mineral Statistics of Canada, by H. P. Brumell, (81 pp.) Report of the Division of Mineral Statistics and Mines, by E. D. Ingall and H. P. Brumell, (123 pp.) Annotated list of the minerals occurring in Canada, by G. C. Hoffmann, (67 pp.)

6. *Notes on Brazilian Mineralogy.*—Dr. E. Hussak in the "Boletim da Commissão geographica e geologica do Estado de S. Paulo" No. 7, (40 pp., S. Paulo, 1890,) gives some valuable observations on some minerals and rocks from Southern Brazil.

Heulandite, *mesolite*, *desmine* (stilbite) and *scolezite* are minutely described. They occur in amygdaloidal cavities in the great trap sheets of presumably Triassic age that abound in Southern Brazil, in association with calcite, chalcedony, chloritic minerals, native copper, etc. The heulandite and mesolite were from the Serra de Botucatú; the stilbite from the Serra de Brotas, and the scolezite from Santa Catharina. The form and optical characters of these zeolites are given and also the following analyses:

	SiO_2	Al_2O_3	CaO	Na_2O	K_2O	H_2O
Heulandite,	58·10	16·67	5·90	0·61	3·26	16·16 = 100·70
Mesolite,	47·61	26·80	7·08	7·80	----	12·11 = 101·40
Stilbite,	60·82	16·67	4·25	1·73	----	18·12 = 101·59
Scolezite,	45·96	26·03	13·53	----	----	13·67 = 99·19

A careful study was made of the virgin auriferous gravel from the valley of the Ribeira. From an abandoned placer mine on the Pedro Cubas, a small branch of the Ribeira, the following species were identified: *Andalusite*, *chiastolite*, *staurolite*, *tourmaline* and *corundum* all abundant; magnetite, *titaniferous magnetite*, *ilmenite*, *rutile* (with sagenite) *anatase*, *titanite*, *zircon*, *gold*, *native*

iron and an *undetermined mineral*, rare. The most abundant and characteristic of these species, andalusite, chiastolite, tourmaline and corundum, are typical of schists (phyllites) altered by contact with eruptive rocks, and since the river Pedro Cubas flows mainly over schists with frequent injections of granite, the association suggests that the gold may be a contact mineral. In the washings from the sands of the main stream (Ribeira) these contact minerals (except tourmaline) are entirely lacking and the most abundant minerals are indicative of crystalline schists, with probably, granite and syenite.

In regard to the occurrence of the *native iron*, it is noted that grains of the size of several millimeters are found. They are irregular battered flakes with metallic luster, and strongly magnetic, that exposed to damp air soon become rusty. In order to determine if these grains came from the iron instruments of the old miners, gravel that was unquestionably virgin was extracted with wooden instruments. The washing gave as great an abundance of iron as those from the gravel heaps previously washed by the old miners.

Among the other notes, which include an account of pseudomorphous crystals of leucite in phonolyte, the occurrence of corundum in São Paulo, etc., may be noted a description of *phyllites with ottrelite and magnetite from São Paulo.* In the zone of phyllites traversed by the river Tieté, layers rich in ottrelite are met with intercalated with others entirely free from this mineral. The ottrelite is in discs or distinct hexagons of about $0{\cdot}25^{mm}$ diameter. Basal sections show distinct cleavage in two directions, making an angle of 120° approx. Pleochroism tolerably strong between plum-blue and olive-green. Angle of optical axes very small and the inclination of the bisectrices to the vertical axis also small. In the rectangular longitudinal sections pyramidal faces are occasionally seen showing the crystals to be deformed hexagons. Polysynthetic twins parallel to (001) and an hour-glass structure shown by the arrangement of inclusions are almost constant. An intergrowth according to the base of two individuals, one full of twin lamellæ and the other free from them was observed. In another case the twins presented a wedge shape. Crossed and contact twins according to one of the faces of the dome are also common, the angle of inclination of the basal faces being between 110° and 125°. Similar twins are described by d'Achiardi from the Apuan Alps and are seen in preparations from the Ardennes.

Basal sections often show a distinct division into three rhombic fields with extinction parallel to the diagonals of the rhombs. As from its optical properties ottrelite is certainly monoclinic, this twinning should be referred to that often observed in mica, that is, twinning planes normal to the base (001) and parallel to the edge (001) : (110).

In longitudinal sections the basal cleavage is very distinctly indicated by lines parallel to the basal edges. A prismatic cleavage indicated by lines normal to the base is also distinct. Lines

forming an angle of 72° with the base are frequently seen between crossed nicols; the extinction is at times parallel to the edges of the base, but generally with a slight inclination (maximum 15°). Pleochroism strong; c = greenish yellow, b = plum-blue, a = olive-green.

The layers of schist with ottrelite often alternate with layers of the thickness of the finger of schist with magnetite and of normal schist free from mineral inclusions.

7. *Estimation of the Optical Angle:* A correction by ALFRED C. LANE. (Communicated).—In my article on the estimation of the optical angle in this Journal,* I notice an error, which I knew enough to have avoided, as the whole subject was long ago thoroughly treated in the "Mineralogie Micrographique" of Fouqué and Lèvy. The maximum extinction-angle in the prismatic zone of common hornblendes is *not* the clinopinacoidal section. This the above writers explained theoretically and I have experimentally verified the fact. The extinction-angle increases slightly and then decreases, and even on the cleavage faces the extinction-angle is but little less than in the clinopinacoidal section.

8. *Systematic Mineralogy based upon a Natural Classification*, with a general introduction, by THOMAS STERRY HUNT. 391 pp. 8vo. New York, 1891. (The Scientific Publishing Company.)—This volume is a development of Dr. Hunt's views on mineral classification, as in part before brought out, more particularly in the volume entitled "Mineral Physiology and Physiography." The work covers, however, a rather wide range. It begins with a historical summary of the different systems since the time of Werner; then follows an explanation of the principles of chemistry and chemical notation as related to the subject in hand, and further the special subject upon which the author has laid most stress: the relation of specific gravity, hardness and solubility to mineral condensation, finally a chapter on crystallization. This occupies about one-half the work, after which follow the "new mineralogical classification" and synopsis of mineral species; in the latter the successive species recognized by the author, arranged by genera in tabular form with summary of chief characters, are provided with dual Latin names after the methods of Natural History and further each "genus" is briefly characterized. For an understanding of the methods employed and detailed results reached, the student must be referred to the original volume. How far the new system and nomenclature are permanent contributions to science, the future will show.

9. *The Phosphates of America.* When and how they occur; how they are mined, and what they cost. With practical treatises on the manufacture of sulphuric acid, acid phosphate, phosphoric acid and concentrated superphosphates, etc; by FRANCIS WYATT. Second Edition. 187 pp. 8vo. New York, 1891. (The Scientific Publishing Company.)—The phosphate industry in this

* This Journal, vol. xxxix, 1890, p. 56, line 1.

country has been of remarkably recent development, when its present importance is considered. It was in 1867, that the mining of the phosphatic deposits in South Carolina commenced, while the mining of apatite in Canada dates only from 1872. It is not strange then, that an interesting, well illustrated and thoroughly practical book upon this subject has been appreciated at once, as shown by the fact that the first edition was exhausted before it had been on sale more than a few days. The scope of the work is given in the comprehensive title. The most original part of the book and perhaps that in which most interest will be felt is the chapter upon the newly discovered phosphate deposits in Florida, at which mining was not fairly begun until 1889. A good map of the state shows the points where operations are now being carried on, and some sixteen excellent full page illustrations give a good idea of the methods of occurrence, of exploitation, etc.

9. *The Kiowa Co. (Kansas) Meteorites;* by ROBERT HAY. (Communicated)—This spring some more meteorites were found, which extend the area of the find as described by Kunz, Snow and Winchell nearly a mile farther east and increase the number of meteorites *several thousand.* One mass eighty pounds in weight has been obtained, but the rest of the find represents a new feature in the remarkable fall. There has been one distinct meteorite of nineteen ounces in weight besides the large one, but the rest were found in groups of small meteorites from about a pound in weight to the size of a pea. Each group was scattered over an area of 15 to 30 square yards. The larger individuals of the groups show themselves true Pallasites and even some very small ones, but many of these latter are largely oxidized, the metallic iron having all disappeared. All stages of oxidation are shown in each group. The large mass and three groups—the smallest weighing three pounds and numbering 400 individuals—are in possession of the writer, Junction City, Kansas.

10. *Geological Survey of Kentucky, John R. Procter, Director.*—This survey has recently published a report of 20 pages, by G. M. SULLIVAN, on the Geology of parts of Jackson and Rockcastle Counties, with a colored geological map.

OBITUARY.

HENRY NOTTIDGE MOSELY, the able Naturalist of the Challenger Expedition of 1872 to 1876, and since 1881 Professor of Human and Comparative Anatomy at Oxford, died on the 10th of November last, at the age of forty-seven.

PHILIP HERBERT CARPENTER, Science-Master of Eton College, and the author of extensive elaborate researches on the structure of echinoderms and especially living crinoids, died October 21, aged thirty-nine years. Mr. Carpenter was the fourth son of Dr. W. B. Carpenter.

APPENDIX.

Art. XI.—*The Skull of Torosaurus;* by O. C. Marsh. (With Plates II and III.)

In this Journal for September last, the writer described a new and remarkable genus of *Ceratopsidæ*, represented by two well-marked species.* In the type specimen on which the genus was based, the greater portion of the skull is preserved, and this presents so many points of interest, that a figure of it, one-twentieth natural size, is here given in Plate II. The second species is represented also by the skull, which, although not complete, supplements the type in several important respects, and figures of its posterior portions are likewise given in the accompanying plates. Both specimens are of gigantic size, one skull measuring five and one-half feet across the parietal crest, and the other is nearly as large. They differ widely, moreover, from the huge horned Dinosaurs hitherto found in the same general horizon, and present characters in the skull of much interest.

In *Torosaurus latus*, the species first described, the skull appears wedge-shaped when seen from above, as shown in Plate II. The facial portion is very short and pointed, and somewhat suilline in form. The nasal horn-core is compressed, with a sharp apex directed forward. The frontal horn-cores are large, and strongly inclined to the front, extending apparently in advance of the nasal protuberance. The long, slender squamosals diverge rapidly as they extend backward, their outer margins being nearly on a line with the facial borders in the maxillary region.

* This Journal (III), vol. xlii, p. 266, September, 1891. See also vol. xli, p. 167, February, 1891.

The parietal forms more than half of the upper surface of the skull, and is the most characteristic element in its structure. In the posterior part are two very large apertures, oval in outline, with their outer margin at one point formed by the squamosal. The rest of the border is thin and somewhat irregular, showing that the openings are true fontanelles. This is still better seen in the second species represented in the same Plate, fig. 2, *f'*. In the latter specimen, however, these vacuities are entirely in the parietal, a thin strip of bone separating them on either side from the squamosal. A second pair of openings, much smaller, apparently the true supra-temporal fossæ, are shown in the type specimen. These are situated mainly between the parietal and squamosal, directly behind the bases of the large horn-cores. (Plate II, fig. 1, *c*.) The same apertures are represented in the genus *Triceratops* by oblique openings, as in the skull shown on Plate III, fig. 4, where the front border of each is formed by the post-frontal.

Between these openings, in the type of *Torosaurus*, is a third pair of apertures (Plate II, fig. 1, *c'*). These are quite small, nearly circular in outline, and entirely in the parietal, although probably connected originally with the supra-temporal fossæ. Another pair of still smaller foramina may be seen in the same skull, close to the median line, and separated from each other by the anterior projection of the parietal. A deep groove leads forward to each of these foramina, along the suture between the parietal and post-frontal. The position and direction of these perforations suggest that they may correspond to the foramen seen in *Triceratops*, and shown on Plate III, fig. 4, *x*.

The extreme lightness and great expanse of the posterior crest in *Torosaurus* make it probable that it was encased in the integuments of the head, and that no part of it was free. The outer borders of both the parietal and the squamosals show no marginal ossifications, as in the other known genera of the group, but the presence of a large, separate, epijugal bone in one specimen suggests that epoccipitals may yet be found.

The open perforations in the parietal which have suggested the name *Torosaurus*, readily separate this genus from all the gigantic species hitherto known in the *Ceratopsidæ*, but may perhaps be found in some of the smaller and less specialized forms, from lower horizons of the same formation.

With the successive changes in the parietal there were corresponding variations in the squamosals, and these bones also will serve to distinguish the principal genera from each other. In Plate III, the squamosals of four genera of this group are shown, and the wide difference between them, when seen from

the inside, is especially noticeable. In figure 1, of this plate, the long, slender, right squamosal of *Torosaurus*, with its smooth outer border, is well represented. In figure 2 is seen the same bone of *Sterrholophus*, with a serrate outer margin, and smooth inner surface, also shown in figure 5. Next, in figure 3, is the small, short squamosal of *Ceratops*, nearly bisected by its deep quadrate groove. The free sculptured border of both the parietal and squamosals of *Triceratops* is clearly shown in both figures 4 and 6, especially in the latter, where the contrast with the corresponding parts in figure 5 is noteworthy.

Three other generic names have been applied by Cope to remains of *Ceratopsidæ* found in this country, namely: *Agathaumas*, *Polyonax*, and *Monoclonius*.* The first of these was based on part of a skeleton without the skull, found in Wyoming. The second name was given to various fragments from Colorado, including parts of horn-cores, regarded as ischia, but these may all be the same generically as the preceding specimen. The third name, *Monoclonius*, was used for a skeleton from Montana, with parts of the skull and teeth preserved. This animal was one of the smallest of the group, while the other remains pertained to reptiles of larger size, but not of the gigantic proportions of those more recently described. So far as can be judged from the descriptions and figures of the type specimens, the three generic names just cited cannot be used for any of those previously mentioned in this article. A comparison of the principal characters will place this beyond reasonable doubt.

In the type of *Agathaumas*, the remains best preserved are in the pelvic region, which according to Cope possesses the following features. The ilium has no facet nor suture for the pubis at the front of the acetabulum, and the base of the ischium is coösified with the ilium. There are eight, or perhaps nine, sacral vertebrae, with the neural spines of the first five mere tuberosities. The diapophyses are in pairs, and the last sacral vertebra is reduced and elongate. These characters, and some others found in the description cited, are certainly distinctive, but do not apply to any of the allied fossils described by the writer. Portions of the type specimen, moreover, are in the Yale Museum, as well as other remains from near the same locality. The fossils described as *Polyonax*, and other similar specimens collected in the same region, afford at present no evidence for separation from *Agathaumas*.

*Cretaceous Vertebrata, p. 53, Plates IV, V and VI; p. 63, Plates II and III, 1875. Also Proceedings Philadelphia Academy, p. 255, 1876, and American Naturalist, p. 154, 1886, and p. 715, Plates XXXIII, and XXXIV, for 1889, issued in 1890.

The small dinosaur, about as large as a Rhinoceros, for which the name *Monoclonius* was proposed, is perhaps generically distinct from *Agathaumas*, but no conclusive evidence of this has yet been presented. The description given makes the teeth, dorsal vertebrae, and pelvis, different from those of any of the larger forms, and the T-shaped parietal (figured first by Cope as an episternal bone), is especially distinctive. None of the other known *Ceratopsidæ* have the parietal fontanelles except *Torosaurus*, one of the most gigantic forms discovered, and this genus differs from *Monoclonius*, as described, in various important points. The very long frontal horn-cores, directed forward, the narrow, elongate squamosals, the absence of a median crest on the parietal, as well as the form and anterior connections of this bone, all serve to clearly distinguish the former from the latter.

These points, and others relating to the nomenclature of the *Ceratopsidæ*, will be fully discussed in a later communication, when the large acquisitions recently secured by the writer's able assistant, Mr. J. B. Hatcher, are ready for description.

New Haven, Conn., Dec. 22, 1891.

EXPLANATION OF PLATES.

PLATE II.

FIGURE 1.—Skull of *Torosaurus latus*, Marsh; seen from above.
FIGURE 2.—Posterior crest of *T. gladius*, Marsh; seen from above.

c, supra-temporal fossa; *c'*, anterior temporal foramen; *f'*, parietal fontanelle; *h*, horn-core; *h'*, nasal horn-core; *p*, parietal; *s*, squamosal.

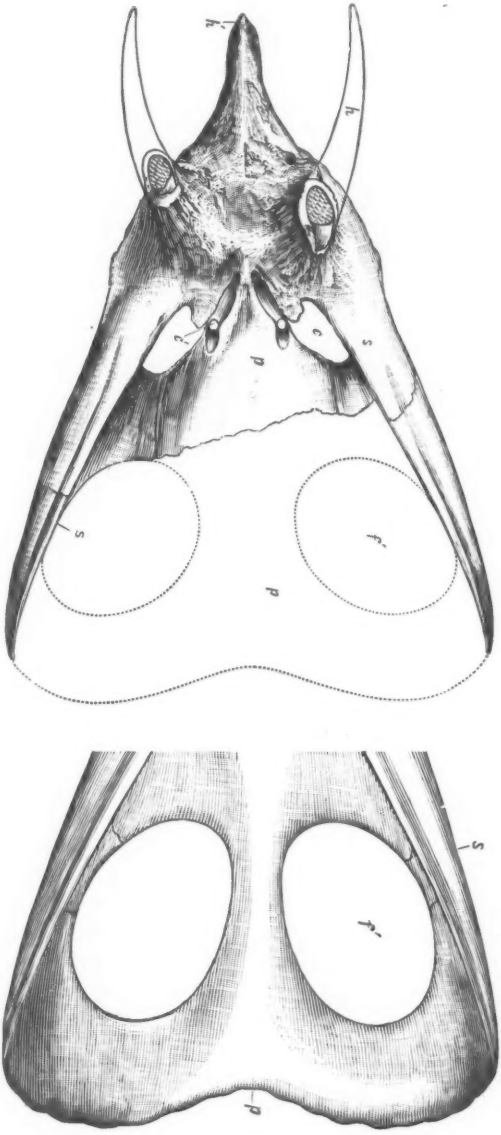
Both figures are one-twentieth natural size.

PLATE III.

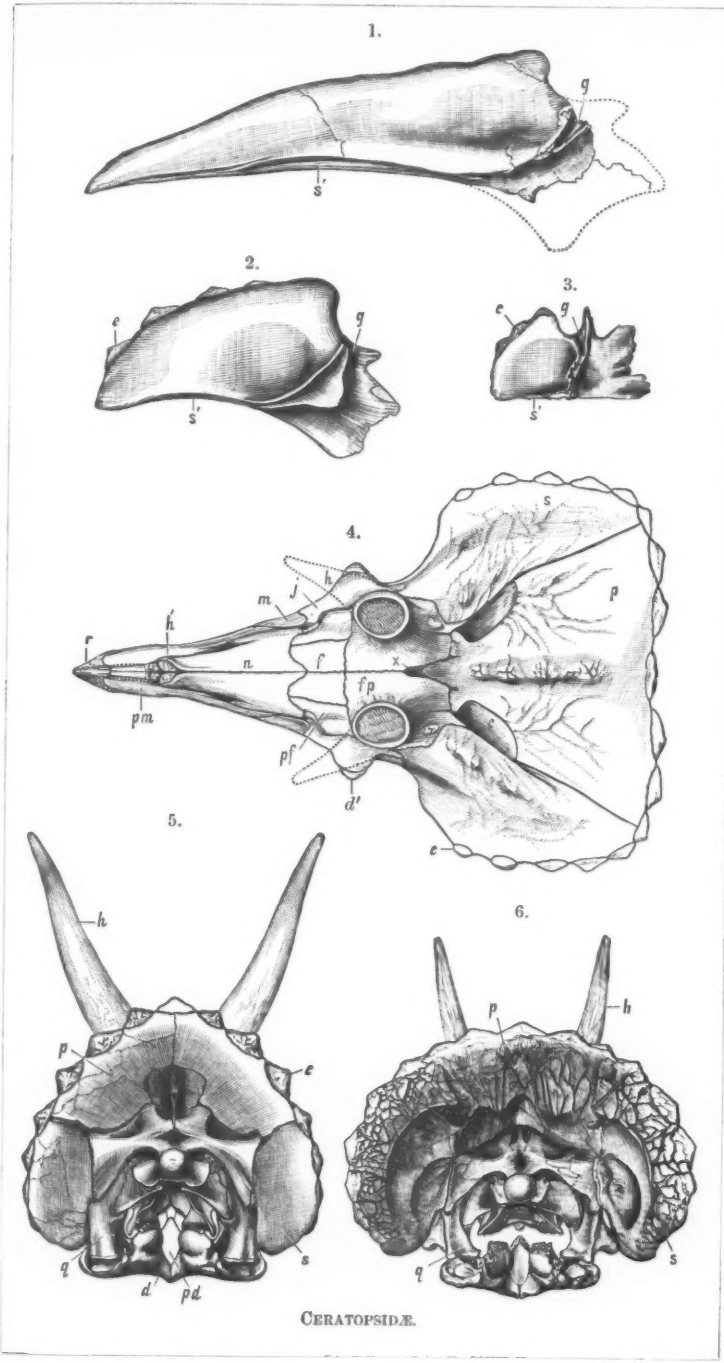
FIGURE 1.—Right squamosal of *Torosaurus gladius*; inner view.
FIGURE 2.—The same of *Sterrholophus flabellatus*, Marsh.
FIGURE 3.—The same of *Ceratops montanus*, Marsh.
FIGURE 4.—Skull of *Triceratops serratus*, Marsh; diagram; seen from above.
FIGURE 5.—Skull of *Sterrholophus flabellatus*; seen from behind.
FIGURE 6.—Skull of *Triceratops prorsus*, Marsh; seen from behind.

d, dentary; *d'*, epijugal bone; *e*, epoccipital; *f*, frontal; *g*, groove for quadrate; *fp*, postfrontal; *j*, jugal; *m*, maxillary; *n*, nasal; *pf*, prefrontal; *pm*, premaxillary; *s'*, suture for parietal.

All the figures are one-twentieth natural size.



1. Skull of TOROSAURUS LATUS, Marsh. 2. TOROSAURUS GLADIUS, Marsh. Both figures are one twentieth natural size.



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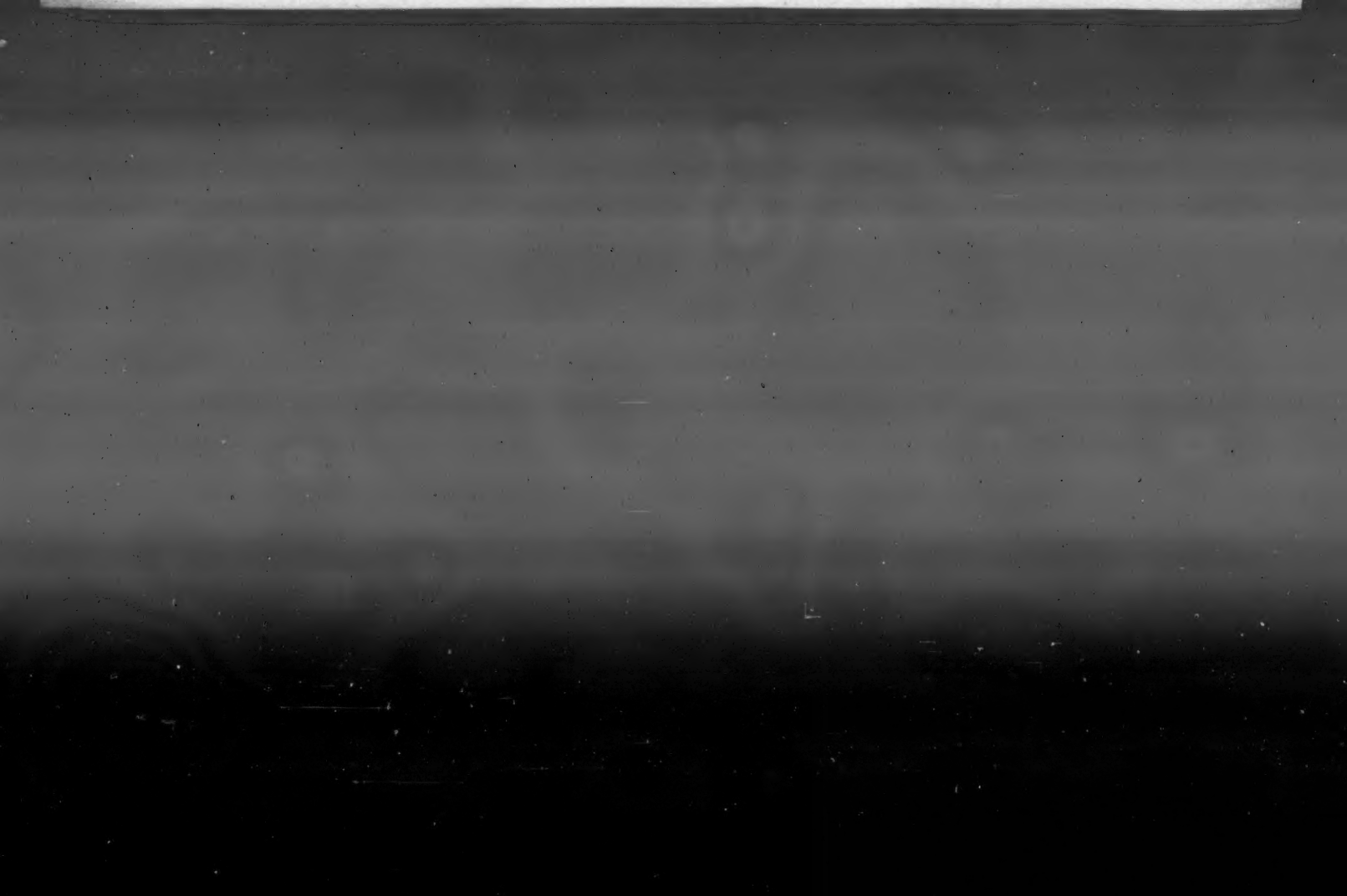

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